DEX ISSUE

GENERAL MOTORS ENGINEERING JOURNAL

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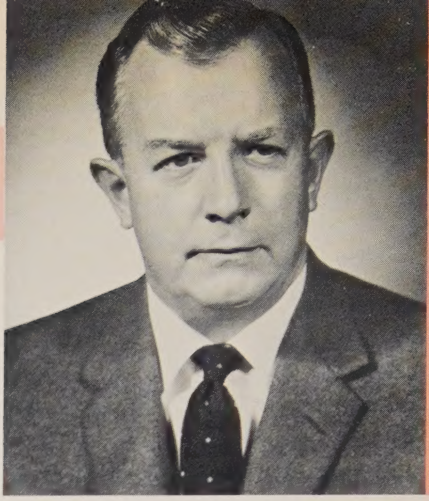
for educators
in the fields of engineerin
and allied sciences

Electrical Power Generation

On Responsibility



Recently, I was reminded of the excellent work being done by engineering and scientific societies in promoting an understanding of their professions, and in the development of high standards and codes of ethics. I was impressed particularly by their programs for assisting members in personal plans for self-development, and by their recognition of the obligation of professional people to be active, responsible citizens as well as professional men.

I think that too often in the past many of us have been inclined to blame the economists, the statesmen, the politicians and others for some of the problems we have faced as citizens and as individuals. Perhaps they have not always done all they should. It must be said, however, that throughout history they have had to adjust to radically changed physical environments engendered by new inventions and creations. Certainly they have a right to expect, for example, that the engineer and scientist—as responsible citizens—share with them some of the responsibility for directing the impact of their own creations.

In the world of tomorrow, I believe that a realization of such mutual responsibilities is essential if we are to survive and progress. Whether in business or professional life, national or international relations, I know of no greater need than that for mutual respect and understanding between individuals and between groups,—between engineer and economist, between subordinate and superior, between worker and intellectual. It always has been amazing to me, for example, how so many personnel problems in business have been so quickly solved when those involved made the effort to apply just a few principles of human relations.

Similarly with respect to some of the problems of the space age, about which we hear so much, I believe the real danger lies in the individual succumbing to a belief that, as an individual, he is impotent to do anything about them; that they will take care of themselves; or that we can pay or elect others to handle them for us.

By default or otherwise, each of us will not be able to avoid now or in the future, making decisions with respect to our part in these problems of the day. Each of us, of course, must decide in his own mind just how and to what extent he can contribute—on the job and in his profession, in the civic, social and other phases of his life.

I believe that engineers and scientists, by virtue of their training, are particularly well qualified to lead the way in these areas. I hope that today's graduates will take full advantage of the many good suggestions for self-development put forth by such societies as the Engineers Council for Professional Development, and use these suggestions to improve and broaden their knowledge and experience, and to take their place as responsible citizens of the world.

Louis G. Seaton

Louis G. Seaton,
Vice President in Charge
of Personnel Staff

THE COVER

One of the jobs of an engineer is to devise economical ways to convert energy from one form to another form useful for his purpose. A familiar example is the conversion of mechanical energy into electrical energy by means of the electrical generator, the subject of this issue's cover design by artist Richard P. Renius. In a view through a silhouette of an armature, this cover design depicts the basic principle of the generator: the rotation of a conductor in a magnetic field produced by the opposite poles of an electromagnet. Depending on how the ends of the conductor are connected, either a d-c or a-c generator can be devised. Each type of generator has a specific application. For example, a d-c generator is used to convert the mechanical energy of a Diesel engine into electrical energy to drive the traction motors of a Diesel-electric locomotive (top views, front and back covers). A recent application of an a-c generator is in a transportable Diesel-powered electrical generating plant for peaking and reserve capacity (bottom views, front and back covers).

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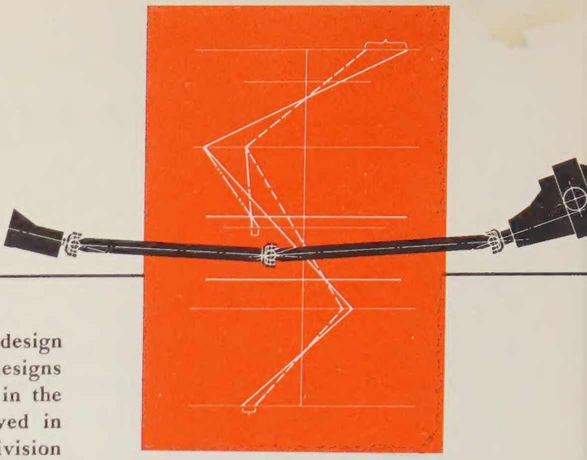
The Application of Nomography to the Design of a Two-Piece Propeller Shaft System



The design of a two-piece propeller shaft system is developed during the early design stages of the car frame and underbody. In many cases, propeller shaft system designs must be developed almost daily to meet new requirements imposed by changes in the still-flexible design of the frame and underbody. To decrease the time involved in developing an optimum design for a propeller shaft system, Cadillac Motor Car Division engineers applied nomography to replace the previously used method of making a full-size layout for each proposed system. The nomograms developed save valuable time in the repetitive solution of the equations required to determine the forces acting on the system at a specific design position of the rear axle. In addition, modifications to an original design can be made directly on the nomograms, which provide the designer with a closer insight into the inter-relationship between the design variables.

A TWO-PIECE propeller shaft system transmits torque from the output shaft of the transmission to the rear axle drive pinion. Three Cardan-type universal joints (sometimes called Hooke's joints) are used to connect: (a) the front propeller shaft to the transmission output, (b) the front and rear shafts together, and (c) the rear propeller shaft to the rear axle drive pinion (Fig. 1). The front propeller shaft is supported by a rubber mounted center bearing.

Since the propeller shaft system is connected to the chassis at three points—the transmission, frame, and rear axle—any disturbance which occurs in the system is transmitted to the passenger compartment. This disturbance may be amplified by resonance of the engine-transmission assembly, the center bearing support, or the rear axle with the propeller shaft excitation. A propeller shaft system, therefore, must be designed to minimize or eliminate propeller shaft excitation. This is accomplished by correctly proportioning the lengths of the front and rear shafts and specifying the proper angles between the shafts for optimum design conditions.

Cardan-Type Joints Produce Unique Force Components

A Cardan-type universal joint connecting two shafts which are not in a straight line has motion characteristics defined by its geometrical configuration. This is evidenced by unequal input and output velocities and torques. Analysis of a Cardan-type joint shows that there exist torques, or couples, in the input and output yokes of the joint which occur in the planes of the respective yokes (Fig. 2). These couples (called secondary couples to distinguish them from the primary, or driving, couple) are of a periodic nature and are approximately equal to a static couple and a rotating couple of equal magnitude. The input and output yokes of the joint experience the secondary couple excitation. The couple in the input yoke is 90 shaft degrees out of phase with the couple in the output yoke.

When three Cardan-type joints are used in an automotive propeller shaft system, each joint contributes secondary moments which are resolved into forces on the shaft supports. The total force on each support is determined by the geometry of the propeller shaft system, the joint angles, and the phasing of the joints relative to one another. The total torsional vibration, determined by a summation of the output velocity fluctuations of the three joints, also is dependent on the joint angles and joint phasings.

Static and Dynamic Forces Occur at Center Bearing Support

The rubber-mounted center bearing support for the front propeller shaft is the support most sensitive to dynamic bearing forces. The design of a propeller shaft system must provide for minimum forces at this support, since high forces at mount resonance will cause a "shudder" in the car.

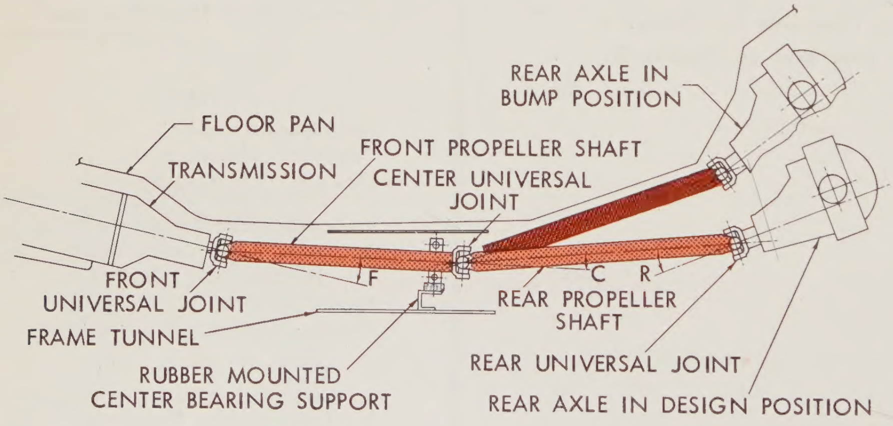


Fig. 1—The two-piece automotive propeller shaft system shown above connects the transmission main output shaft to the rear axle drive pinion. The front propeller shaft is supported by a rubber-mounted center bearing bracket and remains in a fixed position with respect to the car. The rear propeller shaft moves angularly with the motion of the rear axle during driving conditions or under car loading changes. Clearance of the propeller shaft system between the frame and underbody must be maintained at all times. The angles *F*, *C*, and *R* between the front and rear shafts are exaggerated in this drawing. In most cases, the angles between the shafts are no larger than four degrees in the design position.

By **NORBERT J. DENIL**
Cadillac Motor Car
Division

System modifications
can be made directly
on the nomograms

The variables which affect the design of a propeller shaft system are the shaft lengths and the angles between the shafts (Fig. 3). Examination of four possible universal joint configurations (Fig. 4), with the joints phased in 90° increments and the angles between the shafts occurring in only one plane, will aid in developing equations which define the forces acting on the center bearing support. The equations for a dynamic force V_D and a static force V_S are as follows:

$$V_D = \frac{T}{2f}\left[\tan F + \alpha\left(\frac{f+d}{r}+1\right)\tan C + \beta\left(\frac{f+d}{r}\right)\tan R\right] \qquad (1)$$

$$V_S = \frac{T}{2f}\left[\tan F - \left(\frac{f+d}{r}-1\right)\tan C - \left(\frac{f+d}{r}\right)\tan R\right] \qquad (2)$$

In addition to the static and dynamic forces, an equation for the total torsional disturbance of the propeller shaft system can be developed. The total torsional disturbance is expressed by the torsional effective angle Θ. This is the angle at which a single joint would produce a torsional amplitude equal to that of the propeller shaft system. The torsional effective angle can be expressed as

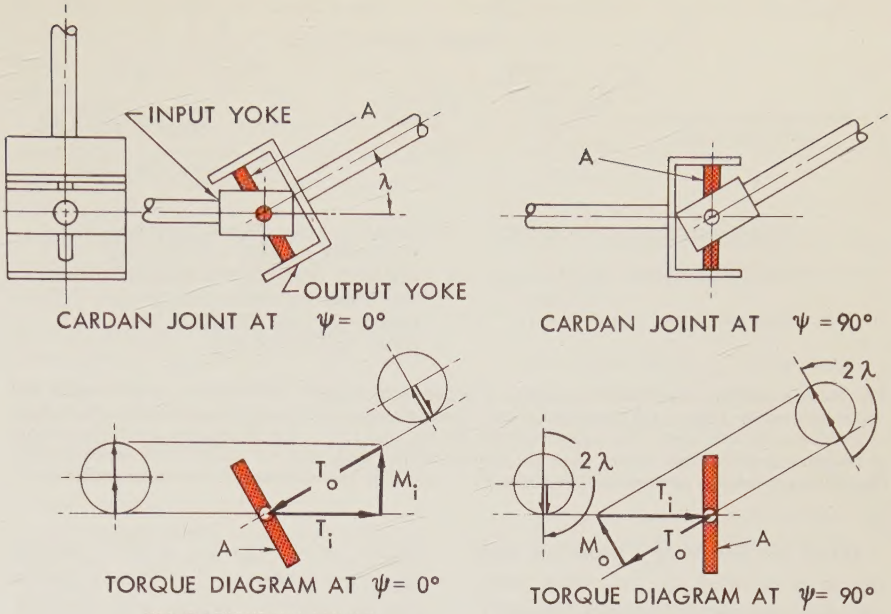
$$\Theta = \left[\!\left[(\tan F)^2+\gamma(\tan C)^2+\delta(\tan R)^2 \right]\!\right]^{\frac{1}{2}} \qquad (3)$$

Rear Axle Motions Must be Considered

The design of a propeller shaft system is based on the selection of a universal joint configuration and values of the shaft system variables (lengths and angles) for a specific design position of the rear axle. The design must provide for:

- Clearance between the propeller shaft, car underbody, and the frame
- Minimum secondary forces and torsional disturbance through the range of rear axle movement.

The design is complicated by the fact that the geometry of the propeller shaft system changes as the position of the rear axle changes relative to the car. The rear axle moves vertically in a path described by the geometry of the rear suspension with changes in car loading, wheel bounce, wheel rebound, and car *squat* during acceleration. In addition, there is rear axle *wind up* (movement of the rear axle about its center when furnishing a wheel reaction torque) due to the elastic rear suspension mounting. The design analysis of a propeller shaft system must take into account the changes between the front and rear shaft angles and the change in the angle between the rear shaft and the rear axle pinion under conditions of rear axle motion, since the joint angles C and R (Fig. 3) will probably not change under these conditions in the manner prescribed by the center bearing force equations (1) and (2).



INPUT SECONDARY COUPLE

$$M_i = T_i\,(\tan\lambda)(\cos\psi)$$

OUTPUT SECONDARY COUPLE

$$M_o = T_i\,(\sin\lambda)(\sin\psi)\sqrt{1+\tan^2\lambda\cos^2\psi}$$

IF λ IS SMALL, THE EQUATION FOR M_o IS:

$$M_o \cong T_i\,(\tan\lambda)(\sin\psi)$$

OUTPUT TORQUE

$$T_o = T_i\left(\frac{1-\sin^2\psi\sin^2\lambda}{\cos\lambda}\right)$$

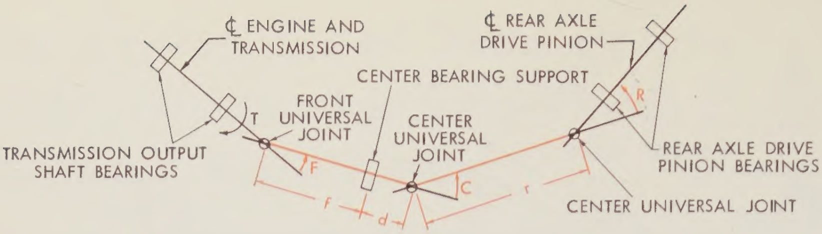
OUTPUT VELOCITY

$$\omega_o = \omega_i\left(\frac{\cos\lambda}{1-\sin^2\psi\sin^2\lambda}\right)$$

Fig. 2—The Cardan-type universal joint is analyzed here in two positions of propeller shaft rotation—at $\psi = 0°$ and at $\psi = 90°$. The angle ψ is defined as the angle of rotation of the input yoke measured from a plane normal to the plane of the shaft. Angle γ is the acute angle between the input and output shafts. Moments in the input and output yokes are determined by equilibrium conditions in the cross, or center, member A of the joint. The secondary input moment M_i and the secondary output moment M_o may each be resolved into a static and dynamic moment. These moments rotate at twice the speed of the shaft. This is shown by projections of M_i and M_o onto the end views of the shaft. The equations show how the input and output secondary couples, output torque T_o, input torque T_i, output velocity ω_o, and input velocity ω_i, vary with the angular position of the shaft.

Layout Method Used for Propeller Shaft System Design

The design of a propeller shaft system is developed early in the design of the car frame and underbody, while their design is still flexible. New propeller shaft designs must be developed almost daily during this period to meet new requirements imposed by changes in the frame and underbody.



F = FRONT UNIVERSAL JOINT ANGLE
C = CENTER UNIVERSAL JOINT ANGLE
R = REAR UNIVERSAL JOINT ANGLE

f = DISTANCE FROM FRONT UNIVERSAL JOINT TO CENTER BEARING SUPPORT (IN.)
d = DISTANCE FROM CENTER BEARING SUPPORT TO CENTER UNIVERSAL JOINT
r = LENGTH OF REAR PROPELLER SHAFT (IN.)
T = INPUT TORQUE (LB-IN.)

Fig. 3—The variables which affect the design of a two-piece propeller shaft system—shaft lengths and angles between the shafts—are illustrated above. The shaft lengths *f*, *d*, and *r* are measured to the centers of the three universal joints. The sign convention for the angles *F*, *C*, and *R* between the shafts consists of assigning positive angle values when the shafts form an angle concave upward and negative when the shafts are concave downward. The angles *F*, *C*, and *R* in this diagram are shown as positive.

When the design of a propeller shaft system is initiated, the following information is on hand or has been estimated:

- Space available between the car underbody and the ground clearance line
- Location of the instant center of rear axle wind up and car squat
- Rear axle wind up angle versus applied torque
- Maximum propeller shaft torque
- Rear axle motion under changes in car standing height.

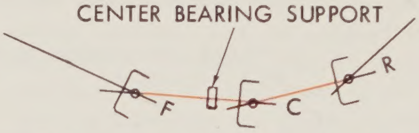
The usual method for designing propeller shaft systems at Cadillac Motor Car Division involved selecting a universal joint configuration (Fig. 4) in which the angle changes estimated from rear axle motion data or wind up data would minimize secondary force variation and allow minimum torsional disturbance.

First, a full-size design layout of the chassis and underbody was made and a propeller shaft system drawn in. The rear axle was then drawn in various positions of passenger load and wind up motions and the three joint angles *F*, *C*, and *R* measured at each position. The dynamic and static forces on the center bearing support and the torsional effective angles at each position were then calculated by applying equations (1), (2), and (3). If the propeller shaft system design was unsatisfactory, which the first attempt usually proved to be, a new full-size layout was made and the process repeated until an optimum design was obtained.

Since new propeller shaft systems had to be designed almost daily, the layout method had some disadvantages as far as the time element was concerned. A certain amount of valuable design time was spent in drawing many full-size layouts, in measuring the required angles, and in making the required calculations. The layout method also made it difficult to determine the best way to obtain an optimum design—that is, which way to change the design—and also to correct a design because of the inability to obtain a direct solution for the amount of change in a variable.

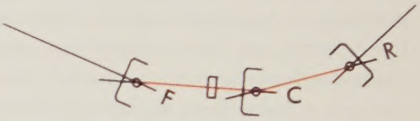
Nomography and Computer Methods Proposed to Replace Layout Method

Although the layout method provided the results desired in propeller shaft design, it was thought that another method might be developed which would provide a savings in time and also provide more flexibility in the design procedure. Two methods were proposed as possible replacements for the layout



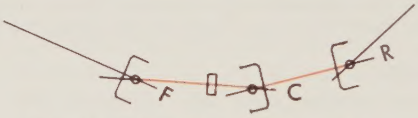
JOINT CONFIGURATION NO. 1

$\alpha = -1$　$\gamma = +1$
$\beta = +1$　$\delta = +1$



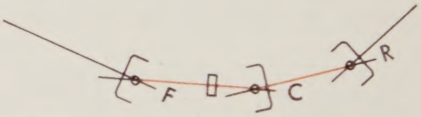
JOINT CONFIGURATION NO. 2

$\alpha = -1$　$\gamma = +1$
$\beta = -1$　$\delta = -1$



JOINT CONFIGURATION NO. 3

$\alpha = +1$　$\gamma = -1$
$\beta = +1$　$\delta = +1$



JOINT CONFIGURATION NO. 4

$\alpha = +1$　$\gamma = -1$
$\beta = -1$　$\delta = -1$

CENTER BEARING DYNAMIC FORCE

$$V_D = \frac{T}{2f}\left[\tan F + \alpha\left(\frac{f+d}{r}+1\right)\tan C + \beta\left(\frac{f+d}{r}\right)\tan R\right] \qquad (1)$$

CENTER BEARING STATIC FORCE

$$V_S = \frac{T}{2f}\left[\tan F - \left(\frac{f+d}{r}-1\right)\tan C - \left(\frac{f+d}{r}\right)\tan R\right] \qquad (2)$$

TORSIONAL EFFECTIVE ANGLE

$$\Theta = \left[\left|(\tan F)^2 + \gamma(\tan C)^2 + \delta(\tan R)^2\right|\right]^{1/2} \qquad (3)$$

Fig. 4—Shown here are side views of four possible universal joint configurations. The joints are phased in 90° increments. The angles *F*, *C*, and *R* between the front and rear propeller shafts occur in only one plane. Analysis of the direction and magnitude of the static and dynamic secondary moments from each of the joint configurations gives the equations shown at the bottom for the static and dynamic forces acting on the center bearing support. The torsional effective angle Θ—the angle at which a single joint would produce a torsional amplitude equal to that of the propeller shaft system—also is defined. The values shown for the angles α, β, γ, and δ are inserted into the equations for a particular joint phasing. The force sign convention (+ or −) indicates the direction of the static force and the direction of the dynamic force when the front drive yoke is vertical. Positive force is considered to be directed to the right of the car in the plan view.

method of design—a nomographic method and a digital computer method.

Nomographic Method

The use of nomograms to represent the propeller shaft system and to provide the means for modifying the design of the system would eliminate the need for making full-size layouts and would allow a faster and more direct solution to the problem. The nomographic method would provide the accuracy required, since experience had shown that slide rule accuracy was sufficient. Most dimensions required to calculate the static and dynamic forces and the torsional effective angle were scaled from the full-size layouts and an accuracy greater than three significant figures was not required. It was felt that any inaccuracy resulting from the use of nomography could be rectified by making a final full-size layout drawing and making minor adjustments to the values for the angles.

Calculations for the torsional effective angle could easily be carried out by a desk calculator or slide rule, although a nomogram also could be developed for this calculation if one was thought necessary.

Digital Computer Method

Two approaches to the design of the propeller shaft system by digital computer methods were considered. The first approach, and the simplest, involved input of the ranges of each of the shaft length and angle variables along with their initial values. The equations could be solved at each standing height of the car using the initial input values. These values then would be incremented one at a time and new force and torsional effective angle solutions obtained. This approach would result in a series of propeller shaft systems with their related force values from which the most desirable system would be selected.

The second approach involved input of an initial set of values. The computer then would proceed to optimize the solution in a manner similar to the one used in a nomographic method—that is, by changing the most appropriate variables and evaluating the result of each change.

Why Nomography Was Used

The digital computer method offered advantages of calculation speed and accuracy. Also, the program prepared for the computer could be used by persons unfamiliar with a propeller shaft system design analysis and the equations involved.

Each of the two proposed computer approaches, however, had some disadvantages. The first computer approach would produce a tremendous amount of output data which would have to be analyzed to select the best solution. This would require too much time. The second computer approach would involve a complicated logic program and a rather involved set of system modification criteria. At the time that a new design method was being sought, there was little experience in propeller shaft design from a logic programming standpoint*.

Another problem associated with the computer approach was the fact that Cadillac did not have a digital computer on the premises. A computer facility was available several miles away at the General Motors Research Laboratories. However, using the computer at this location would remove the possibility of having answers immediately available—an important objective since new propeller shaft systems would have to be developed almost daily. Therefore, it was felt that nomography would be faster than a digital computer in terms of total elapsed time.

Another reason for favoring the nomographic method was that nomograms would provide the designer with a closer insight into the design problem, enabling him to see the best way to approach a solution while still maintaining touch with the physical problem. Also, nomography would furnish the designer a basis for recommending changes in related assemblies, from a clearance and location standpoint. This would allow him a better opportunity to optimize the design. The designer also would retain a "feel" for the problem and thus be in a better position to obtain the best possible design.

For these reasons, it was decided to apply nomography to solve the necessary equations in the design of a propeller shaft system.

Nomograms Had to Meet Specific Requirements

The nomograms for solving the dynamic and static center bearing force equations were developed with the following requirements in mind:

- Each of the quantities in the secondary force equations would be a variable
- Each of the joint configurations (Fig. 4) must be solved for on the same nomogram
- The angle scales of the nomogram must provide for both positive and negative angles (Fig. 3)
- Modifications of the propeller shaft system to simulate axle motion due to acceleration must be possible
- Modifications of the propeller shaft system to provide for center joint height change, engine rotation, or rear axle drive pinion rotation must be possible
- The amount of change in the system variables to give a certain force value must be determined directly on the nomogram.

How the Nomograms Were Developed

Since the dynamic and static force equations (1) and (2) differed only in the terms α, β, and coefficient of tan C, both equations were charted on the same nomogram, referred to as Chart I (Fig. 5).

The equations for the dynamic and static forces were linear and required only multiplication and addition. This made it possible to use linear scales for the angles F, C, and R. This provided, in addition to ease of calibration, a consistent least count over the scale range and an easy setup of schemes for modifying the design of an original propeller shaft system.

To handle the various joint configurations and (+) and (−) angles on the same nomogram, an H (or modified N) type of nomogram was chosen to facilitate multiplication of the joint angles by their respective factors. Chart I, used to initiate the solution of the dynamic and static force equations, is composed of two H-type nomograms—one each for the center and rear angles and their length coefficients.

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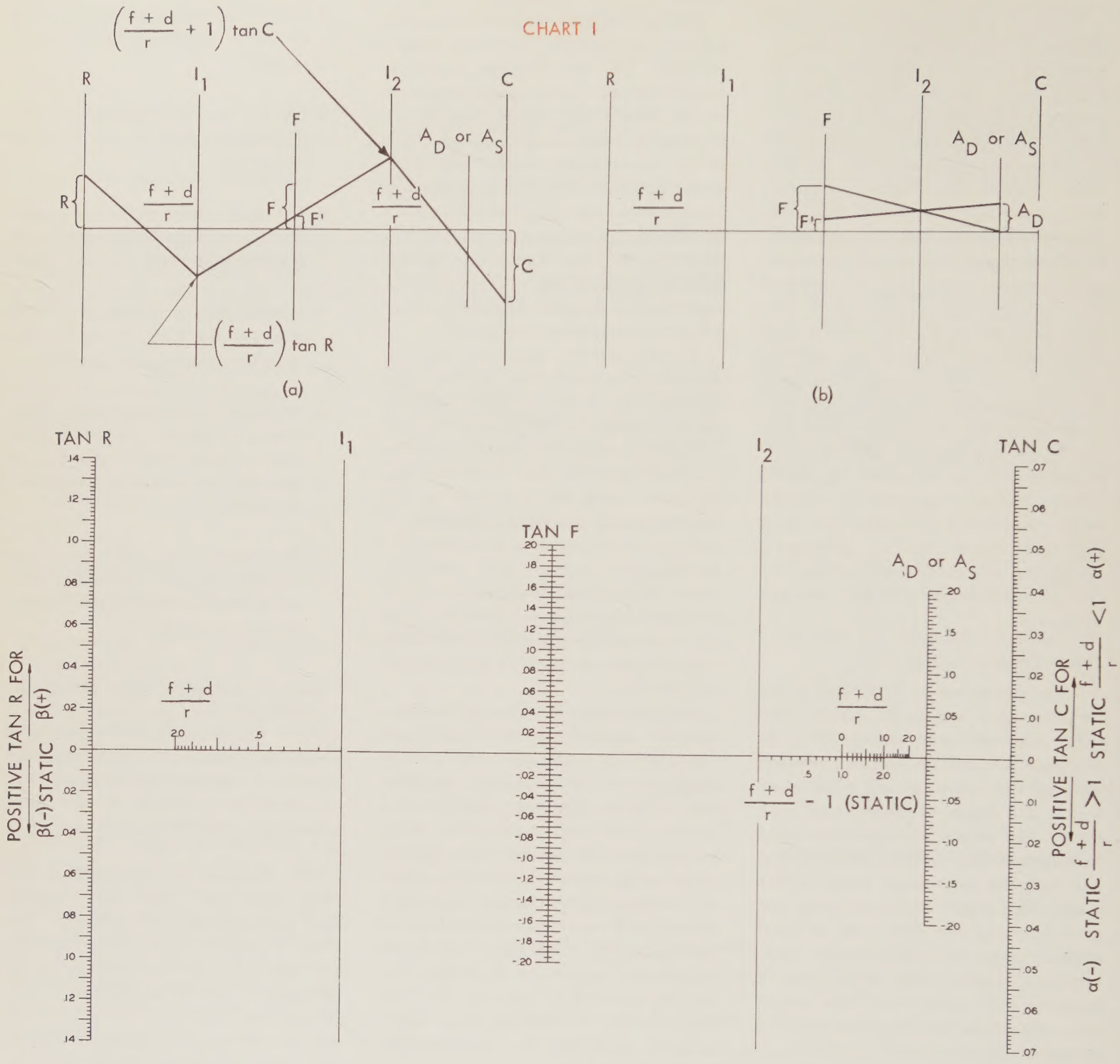
*The development and subsequent use of nomograms for designing the propeller shaft system has since provided this programming experience.

CHART I



CENTER BEARING DYNAMIC FORCE

$$V_D + \frac{T}{2f}\left[\tan F + \alpha\left(\frac{f+d}{r}+1\right)\tan C + \beta\left(\frac{f+d}{r}\right)\tan R\right] \qquad (1)$$

CENTER BEARING STATIC FORCE

$$V_S = \frac{T}{2f}\left[\tan F - \left(\frac{f+d}{r}-1\right)\tan C - \left(\frac{f+d}{r}\right)\tan R\right] \qquad (2)$$

SUB-EQUATION FOR DYNAMIC FORCE

$$A_D = \left[\tan F + \alpha\left(\frac{f+d}{r}+1\right)\tan C + \beta\left(\frac{f+d}{r}\right)\tan R\right] \qquad (4)$$

SUB-EQUATION FOR STATIC FORCE

$$A_S = \left[\tan F - \left(\frac{f+d}{r}-1\right)\tan C - \left(\frac{f+d}{r}\right)\tan R\right] \qquad (6)$$

$$F' = \alpha\left(\frac{f+d}{r}+1\right)\tan C + \beta\left(\frac{f+d}{r}\right)\tan R \qquad (8)$$

Center Bearing Dynamic Force Equation

The following equation for the center bearing dynamic force V_D

$$V_D = \frac{T}{2f}\left[\tan F + \alpha\left(\frac{f+d}{r}+1\right)\tan C + \beta\left(\frac{f+d}{r}\right)\tan R\right] \tag{1}$$

was charted as two sub-equations. The first sub-equation consisted of setting the bracketed quantity of equation (1) equal to A_D as follows:

$$A_D = \tan F + \alpha\left(\frac{f+d}{r}+1\right)\tan C + \beta\left(\frac{f+d}{r}\right)\tan R. \tag{4}$$

The second sub-equation consisted of multiplying the remaining term on the right hand side of equation (1) by A_D to give

$$V_D = \frac{T}{2f}(A_D). \tag{5}$$

Center Bearing Static Force Equation

The following equation for the center bearing static force V_S

$$V_S = \frac{T}{2f}\left[\tan F - \left(\frac{f+d}{r}-1\right)\tan C - \left(\frac{f+d}{r}\right)\tan R\right] \tag{2}$$

also was charted as two sub-equations. The bracketed quantity of equation (2) was set equal to A_S to give the sub-equation

$$A_S = \tan F - \left(\frac{f+d}{r}-1\right)\tan C - \left(\frac{f+d}{r}\right)\tan R. \tag{6}$$

The remaining term on the right hand side of equation (2) was multiplied by A_S to give the second sub-equation

$$V_S = \frac{T}{2f}(A_S). \tag{7}$$

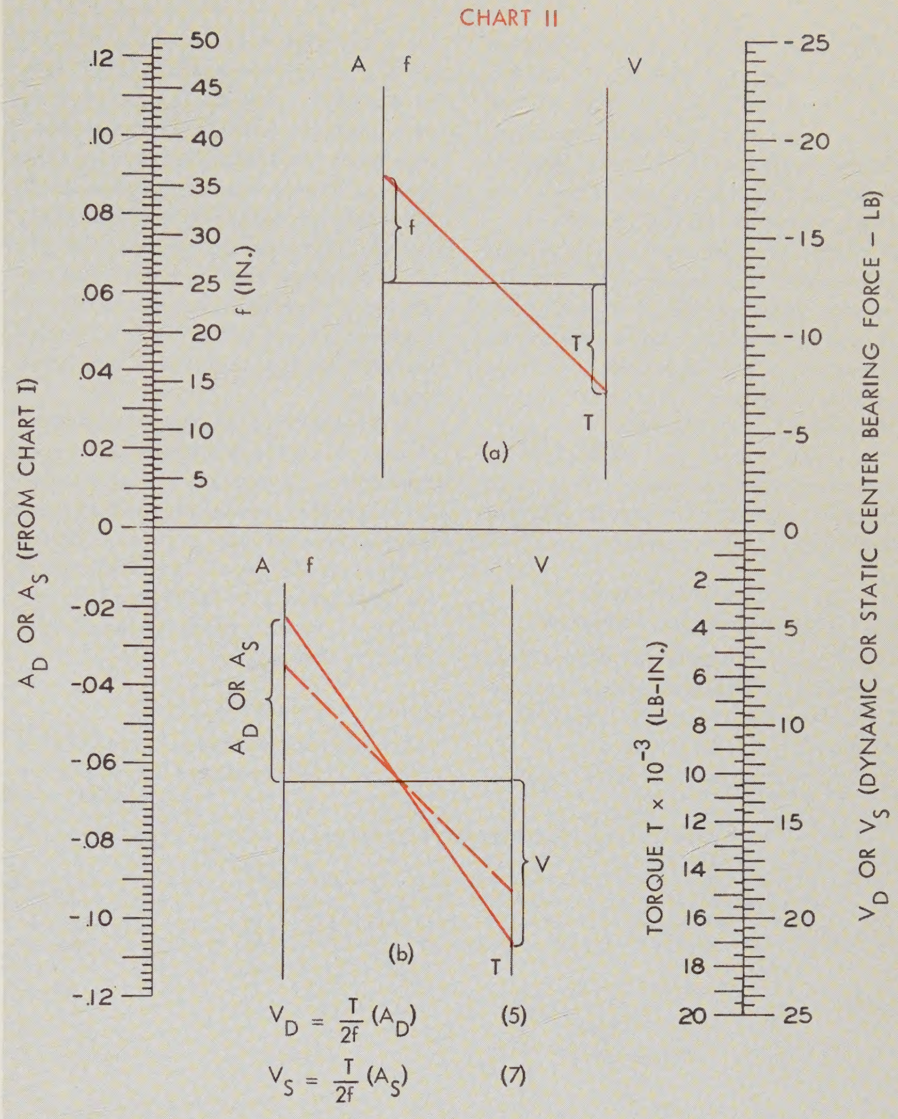


Fig. 6—This nomogram, referred to as Chart II, is used to evaluate sub-equations (5) and (7) for either the dynamic force V_D or static force V_S acting on the center bearing. Values of f and T are first located on their respective scales and a line drawn between them to determine a point on the horizontal index line, as shown in inset (a). The value for either A_D or A_S determined from Chart I is next located, as shown in inset (b). A line is drawn between this point and the point on the horizontal index line and projected until it intersects the scale for the center bearing force.

Fig. 5—This nomogram, referred to as Chart I, is used to initiate the solution of equations (1) and (2) for the dynamic and static forces acting on the center bearing. Specifically, Chart I is used to solve the two sub-equations (4) and (6) shown for the dynamic and static forces. The procedure for evaluating either of these two sub-equations is the same.

To use Chart I, for example, to evaluate the sub-equation for dynamic force, values for α and β are first determined from Fig. 4 for the particular joint configuration to be used. At the same time, directions for positive R and C angles are noted. The values for angles R and C are located on their respective scales. The value for $(f + d)/r$ is determined and located on the proper scales. Lines joining the values for R, C, and $(f + d)/r$ are then constructed to give points on the I_1 and I_2 scales which correspond to the values indicated in inset (a). A line is then drawn between the points on the I_1 and I_2 scales to locate a value of F' on the tan F scale. The value of F' is defined by equation (8). The value for tan F is then located. The difference between the value for the tangent of F and F' is equal to A_D. To read A_D directly, however, a line is drawn between the value for tan F and the zero point on the A_D scale, as shown in inset (b). This construction determines a new point on the I_2 scale. A line drawn between the value for F' and the new point on the I_2 scale and projected until it intersects the A_D scale will give the desired value for A_D. This value is then used in Chart II (Fig. 6) to find the dynamic force V_D.

The sub-equation for the static force is evaluated in the same manner as the sub-equation for the dynamic force using the appropriate value for tan C and the tan C multiplier scales.

Equations (4) and (6) are solved on Chart I (Fig. 5). Equations (5) and (7) are solved on Chart II (Fig. 6). All major calculations and system modifications are performed on Chart I. Chart II is used to transform the result from Chart I into a force quantity.

Chart II is composed of two *H*-type nomograms superimposed so that the answer scale for the first nomogram becomes a multiplier scale for the second nomogram. Chart II is used to evaluate a value or series of values determined on the A_D or A_S scale of Chart I.

In most cases, the static force is secondary to the dynamic force. A check is made, however, to assure that the static force is not excessive.

Design Modifications Performed on One Nomogram

All modifications to the design of an original propeller shaft system are performed on Chart I. Any desired force relationship may be obtained.

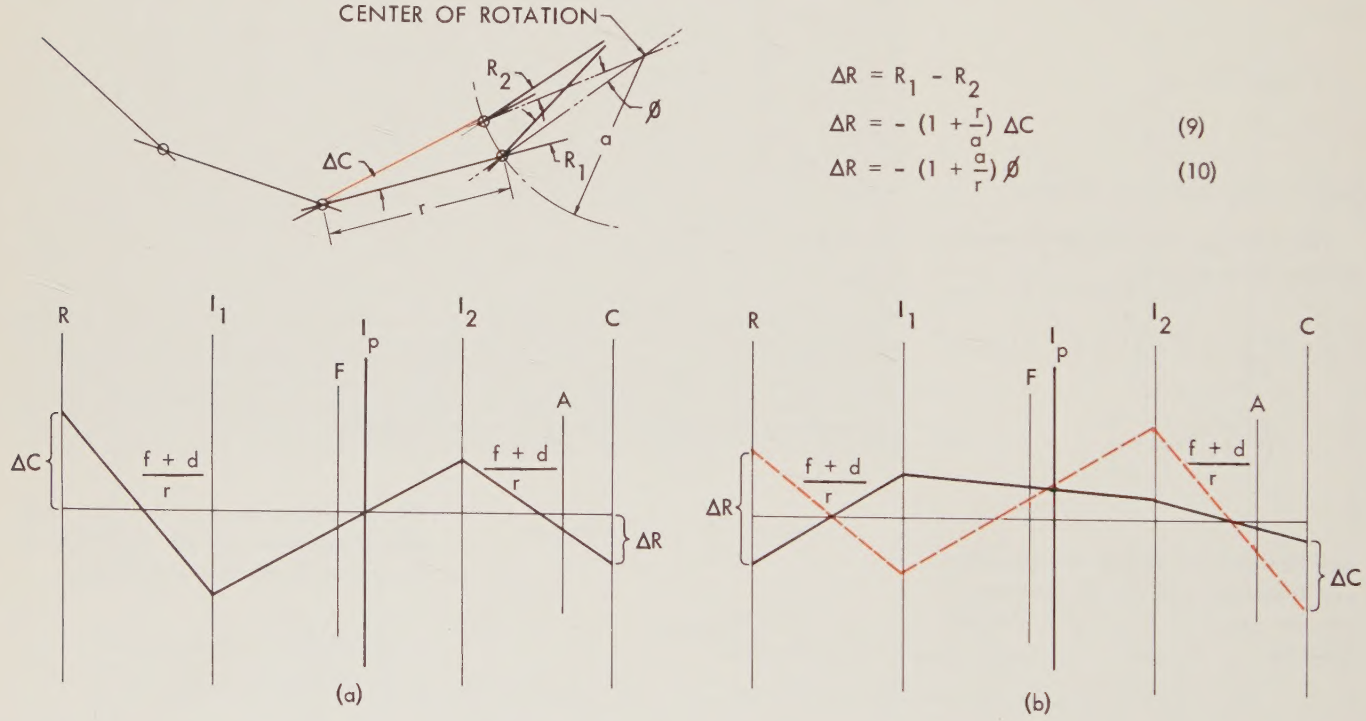
It is evident that the relationship of the system line—that is, that line connecting points between two index lines—to the value of F on the tan F scale determines the force on the center bearing. When the system line intersects the value of F, zero bearing force results. If the system line is pivoted until this intersection occurs, the intersections the system line makes with the indices and the resultant projections on the C and R angles scales will define the shaft angles necessary for the condition of zero bearing force.

If the motion of the system line defines changes in the angles which occur corresponding to rear axle wind up, rotation of the engine centerline or rear axle drive pinion, or change in the vertical location of the center bearing support, the final position of the system line will describe a realistic design change in the propeller shaft system.

System Modifications

Location and construction of the index lines on which the system line is to pivot to provide for modification to the propeller shaft system corresponding to rear axle wind up, rotation of the engine or rear axle drive pinion, and location of the center bearing support are performed by procedures described in Figs. 7, 8, and 9. The equations shown for each modification are approximate. Their accuracy is sufficient, however, since the corrections are made only through small angles.

In the examples illustrated in Figs. 7, 8, and 9, universal joint configuration No. 2 (Fig. 4) is used. This allows a direct solution for the system modifications, since the angle changes described by the system line as it is pivoted about an index intersection bear the correct sign relationships to each other. Rotating the rear axle drive pinion upward (Fig. 7), for example, produces a negative angle ΔR and a positive angle ΔC. With some of the other universal joint configurations, the system line may produce the wrong sign relationship. In this case, the distance traversed on one of the indices is laid out on the opposite side of

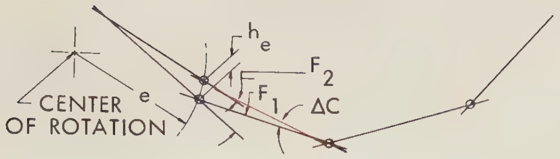


$$\Delta R = R_1 - R_2$$

$$\Delta R = -\left(1 + \frac{r}{a}\right) \Delta C \qquad (9)$$

$$\Delta R = -\left(1 + \frac{a}{r}\right) \phi \qquad (10)$$

Fig. 7—Modifications of the original design of a propeller shaft system to provide for rear axle wind up or rotation of the rear axle drive pinion are performed on Chart I using the procedure illustrated here. Wind up or rotation of the rear axle pinion through an angle ϕ causes the rear joint angle R and the center joint angle C (Fig. 3) to change as stated in equation (9). This angular change is performed on Chart I by first choosing an arbitrary value for ΔC. Equation (9) is then applied to determine a value for ΔR. The values for ΔC and ΔR are located on the tan R and tan C scales of Chart I, as shown in (a). Lines are drawn through these points and the points located for the value of $(f + d)/r$ to give an intersection on the I_1 and I_2 indices. A line is then drawn connecting the intersection points on I_1 and I_2. This line intersects the horizontal scale. At this point, a vertical index line I_p is constructed. Pivoting the system line, shown dotted in (b), about the index line I_p provides for changes in angles R and C according to equation (9). To simulate rear axle wind up, a value for ΔR is calculated using equation (10). This calculated value is added to R and the total value located on the tan R scale. Projecting a line through this point and the point for the $(f + d)/r$ value to the index line I_1 and rotating the system line about I_p gives a value for C on the tan C scale. The system line also can be pivoted about a second index line I_p which is constructed in a similar manner with the a value equal to the distance from the rear axle to the rear universal joint. This procedure simulates rotation of the rear axle drive pinion about the rear axle.



$$F = F_1 - F_2$$

$$F = -\left(1 + \frac{f + d}{e}\right) \Delta C \qquad (11)$$

$$h_e = (f + d)\Delta C \qquad (12)$$

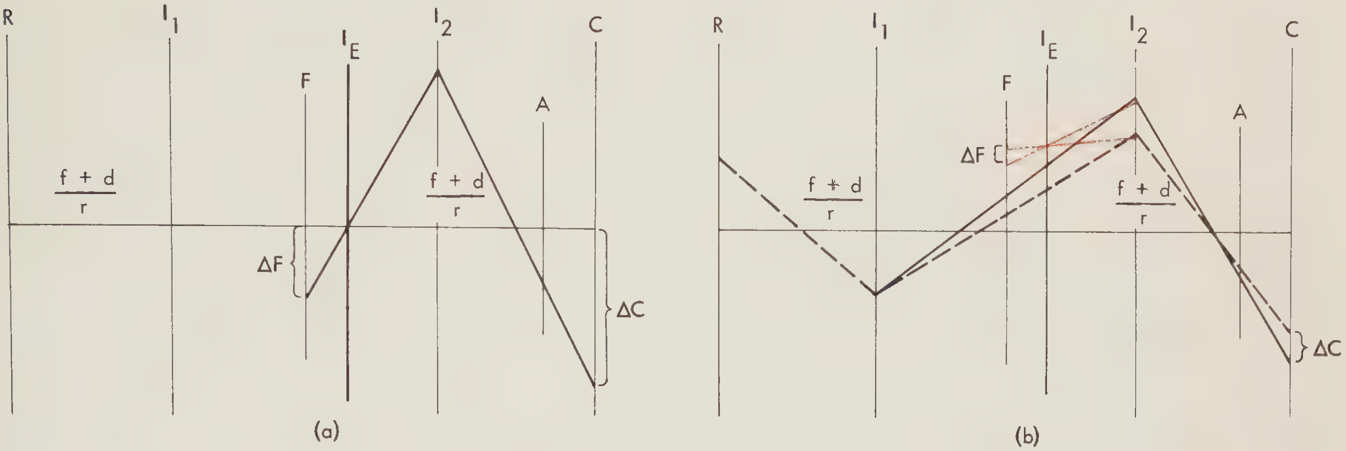


Fig. 8—Illustrated here is the procedure used to modify an original design of a propeller shaft system to provide for rotation of the engine centerline. The modification is made on Chart I. An arbitrary value for ΔC is first chosen and substituted into equation (11) to find a value for ΔF. The values for ΔF and ΔC are then located on the tan F and tan C scales of Chart I. A line is drawn through the point located for ΔC and the point for the value of $(f + d)/r$ until it intersects the I_2 index scale. A second line is drawn between the intersection on I_2 and the point located for ΔF. At the point where this line crosses the horizontal scale, a vertical index line I_E is constructed (a). The value for angle F for the propeller shaft system is connected to the system line (the dotted line in view b) at I_2 with a phantom line (the colored line in view b). Pivoting this line on I_E provides for changes in angles F and C as defined by equation (11). The solid lines in view (b) represent a modified system. This modified system was obtained by rotating the line connecting F to I_2 about the index I_E and connecting the system line from this point on I_1 to the new point on I_2. The change in height h_e of the front universal joint of the propeller shaft system, resulting from these changes in the angle, is defined by equation (12).

the original system line termination and a new system line drawn in.

Torsional Effective Angle

The torsional effective angle Θ is checked by applying equation (3) and using the modified angle values. If the torsional effective angle is excessive, the system is again modified on Chart I until a design is obtained which has satisfactory force and torsional characteristics.

Sample Problem Illustrates Use of Nomograms

To illustrate the use of Charts I and II, the following sample problem is given which involves calculating the dynamic and static forces resulting from a torque given the propeller shaft system at a specific position and then modifying the system to have zero dynamic force by rotating the centerline of the engine. In most cases, the first design of the propeller shaft system is obtained under conditions of zero torque and a wind up correction is then made before proceeding.

Given data:

$f + d = 27$ in.

$f = 24$ in.

$r = 30$ in.

$T = 16{,}000$ lb-in.

$e = 40.5$ in. (Fig. 8)

$\tan F = 0.0699$

$\tan C = 0.0225$

$\tan R = -0.0535.$

Use joint configuration No. 2 (Fig. 4).

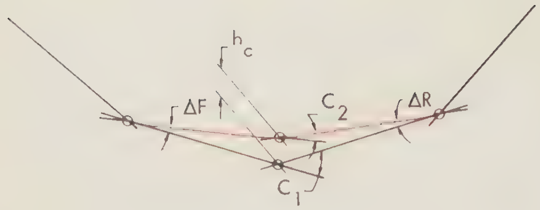
Chart I is used first to evaluate subequation (4) for the dynamic force. From Chart I the value for A_D is found to be 0.0753. Chart II is then used to evaluate the dynamic force V_D, which is found to be 25.1 lb. The static force is then evaluated. A value for A_S of 0.1204 is found from Chart I. This gives a corresponding value for V_S from Chart II of 40.1 lb. Since this static force is off the scale in Chart II, only half of the given value for the torque T was located on the torque scale of Chart II. The value then found for V_S was doubled. The torsional effective angle Θ is calculated by applying equation (3). The angle is found to be 2.88°.

The following procedure is used to modify the propeller shaft system to have zero dynamic force by rotating the centerline of the engine. Equation No. 11 (Fig. 8) is first applied.

$$\Delta F = -\left(1 + \frac{f + d}{r}\right) \Delta C$$

$$\Delta F = -\left(1 + \frac{27}{40.5}\right) \Delta C = -1.67\ \Delta C.$$

This information is then used to construct the index line I_E (Fig. 8). A line is drawn connecting the value of F with the system line on I_2. This construction determines an intersection on index line I_E. A modified system line then is drawn to pass through this intersection and the intersection of the original system line on



$$\Delta C = C_1 - C_2$$

$$\Delta F = - \frac{\Delta C}{1 + \frac{f + d}{r}} \qquad (13)$$

$$\Delta R = - \frac{\Delta C}{1 + \frac{r}{(f + d)}} \qquad (14)$$

$$h_c = (f + d)\Delta F \qquad (15)$$

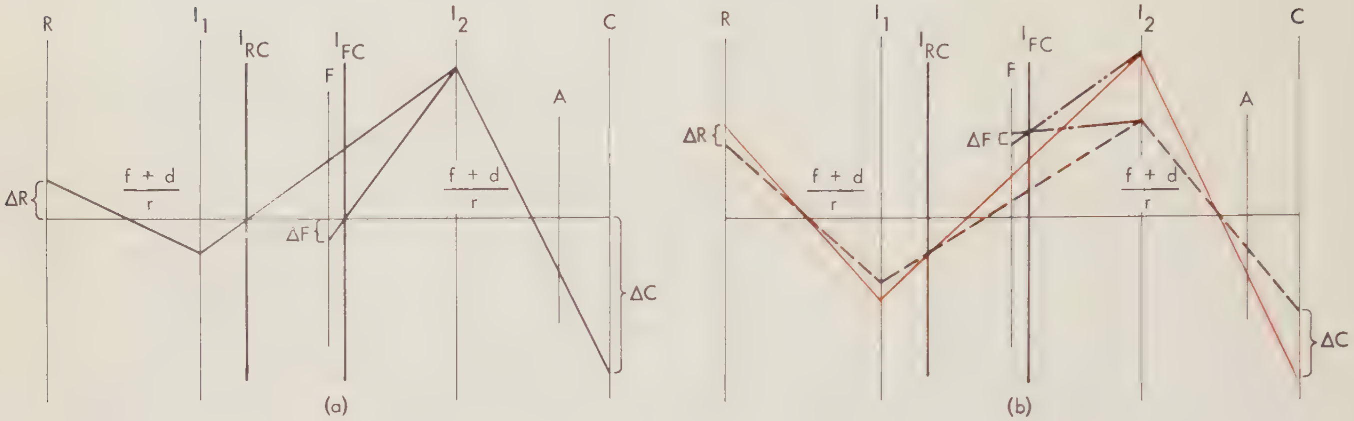


Fig. 9—Raising or lowering the height of the center bearing support is accomplished on Chart I following the procedure illustrated here. An arbitrary value is chosen for ΔC and substituted into equations (13) and (14) to determine values for ΔF and ΔR. The values for ΔC, ΔR, and ΔF are located on the proper scales of Chart I. Lines are drawn through the points for ΔR and ΔC and the points for the value of $(f + d)/r$ until an intersection is made with index lines I_1 and I_2. A line drawn between the intersection points on I_1 and I_2 crosses the horizontal index line at which point a vertical index line I_{RC} is constructed (a). Similarly, a line is drawn between the intersection point on I_2 and the point for ΔF and locates the point on the horizontal scale where the vertical index line I_{FC} is constructed. Pivoting the system line (the dotted line in view b) on I_{RC} provides for changes in angles R and C according to equation (14). Pivoting a line connecting F and the system line intersection at I_2 on index I_{FC} provides for changes in F and C according to equation (13). A modified system, shown by the colored solid lines in view (b), is constructed by first pivoting the line connecting F to I_2 on index line I_{FC}. The I_2 intersection is then connected to the system line intersection with I_{RC} to obtain a new system line. The change which takes place in the height h_c of the center bearing support, resulting from the modified system, is defined by equation (15).

I_2. This modified system line defines new values for angles F and C which will give zero dynamic force.

The modified system gives the following values:

$$\text{Static force} = 29.1 \text{ lb}$$
$$\tan F = 0.0349$$
$$\tan C = 0.0437$$
$$\tan R = -0.0535.$$

The torsional effective angle, calculated for the modified system, is found to be 0.93°. This is an improvement over the original design of the propeller shaft system. The amount of increase h_e in the height of the front propeller joint is determined by applying equation No. 12 (Fig. 8) as follows:

$$h_e = (f + d)\ \Delta C$$
$$h_e = 27(0.0212) = 0.57 \text{ in.}$$

Summary

The application of nomography to the design of a two-piece propeller shaft system has enabled the design engineer to obtain, in a direct manner, an optimum design in a minimum of time. By representing the physical layout of the system as a series of lines on a nomogram, the relationship between the design variables and the best course to pursue toward an optimum design are readily apparent. Because system modifications can be made directly on the nomograms, only one preliminary and one final full-size layout drawing are required, thus saving valuable design time. For the particular application described here, nomography has proven to be a worthwhile tool for providing an accurate and efficient approach to the achievement of a propeller shaft system of optimum design.

Bibliography

Literature related to the subject matter discussed in this paper includes the following:

Burkhalter, R. R. and Mazziotti, P. J., *The Low Silhouette Drive Line*, S.A.E. Preprint No. 691, presented at S.A.E. National Meeting, Detroit, January 11, 1956.

REPRINT AVAILABLE

Reprints of the paper "The Application of Nomography to the Design of a Two-Piece Propeller Shaft System" are available for classroom use. Educators interested in receiving reprints may write to Educational Relations Section, Public Relations Staff, General Motors Corporation, General Motors Technical Center, Warren, Michigan.

A New Method for the Rapid Analysis of Metals in Industrial Waste Effluents

By FRANKLIN L. RACINE
GMC Truck and Coach
Division

Spectrochemical techniques provide fast, accurate analysis of effluent samples

Chemical and spectrographic techniques have been combined at GMC Truck and Coach Division to provide a faster and more accurate determination of the concentration of metals in waste effluent samples. As a result, information is now obtained in only a fraction of the time formerly required by chemical analysis. To date, the new method has been used to determine the presence of only four metals used in plating operations—copper, nickel, chromium, and zinc—but it has the potential to determine many others at the same time and in the same sample.

THE DISPOSAL of chemical wastes resulting from manufacturing processes is an ever present operation in General Motors plants. In many plants, conservation programs are in effect to decrease the discharge of waste chemicals by more complete utilization of materials. Such is the case at GMC Truck and Coach Division. There are, however, certain chemical solutions which cannot be recovered for reuse and which must be discharged. These wastes are chemically treated to render them harmless prior to being discharged into the municipal sewer system.

At GMC, waste effluent samples are analyzed at set intervals by chemical procedures recommended by the American Public Health Association to insure that the chemical constituents of the waste materials are kept within safe limits. These procedures, while effective, have the drawback of requiring an appreciable amount of time. Also, it is difficult to achieve the accuracy desired in the one part per million (ppm) area of concentration.

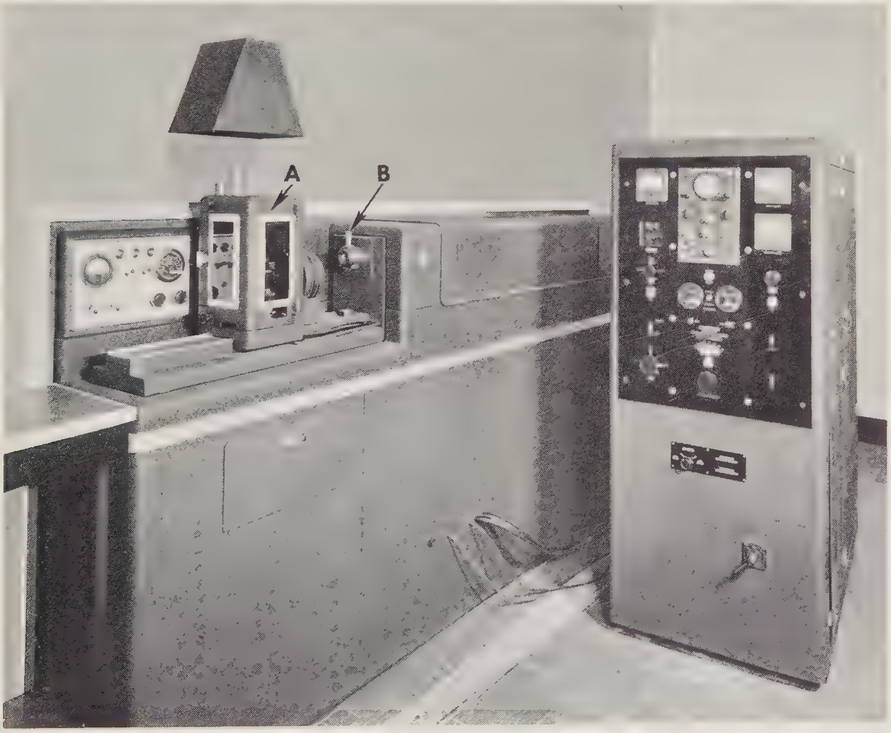


Fig. 1—Shown at the left is the spectrograph used by the Engineering Chemical Laboratory of GMC Truck and Coach Division to analyze industrial waste effluent samples for the presence of metals. The spectrograph has a focal length of two meters and a diffraction grating of 36,000 lines per inch. The slit setting of the spectrograph is 50 microns. A two millimeter gap is used between electrodes. To the right of the spectrograph is a multi-source unit which produces the d-c arc used to excite the effluent samples. This unit houses various electrical components, such as condensers, voltmeters, ammeters, rectifiers, and timers, which allow any type of electrical source desired to be used and controlled to give uniform results. An oscillograph also is provided to study the wave form of a discharge. Two of the spectrograph's components are indicated—the optical stand *A*, where the sample is excited by the d-c arc to produce its characteristic lights, and the optical slit *B*, where light enters the spectrograph. There is an image of this slit produced at every wavelength of light which is characteristic of the elements present in the sample being excited. These images make up a spectrum that is recorded on film.

To decrease the time required for an analysis and also provide for greater accuracy in the area of concentration desired, GMC chemists developed a spectrochemical method for analyzing the presence of metals in an effluent sample. To date, the new method has been used to determine the presence of four metals commonly used in plating operations—nickel, copper, chromium, and zinc—which must be controlled before being discharged into the sewer system as waste material.

How the New Method Works

Effluent samples, adjusted to a pH of 2 or 3 with hydrochloric acid, are placed in clean 300 ml plastic containers. Next, 100 ml portions of the samples are placed in clean 150 ml beakers along with 2 ml of nitric acid, 4 ml of hydrochloric acid, and 1 ml of 1 per cent of lithium nitrate solution.

Lithium is used as the internal standard. The use of an internal standard overcomes non-uniformity of excitation, because any variation will affect both the spectral line of the element and the spectral line of the internal standard in the same way. This is to say that if the excitation was less than normal, both lines would be weaker than normal even though the concentrations were the same. Within limits, however, the ratio of their intensities would be similar.

The samples are heated and evaporated just to the point of dryness without baking. The beakers containing the dried salts then are taken to the spectrographic laboratory (Fig. 1) where 1 ml of 1:1 hydrochloric acid is mixed with the salts. One drop of this mixture is placed in the shallow cup of a ¼-in. center post graphite electrode and excited for 40 sec with a d-c arc using a conical tipped counter electrode. The spectra are recorded on film and developed to obtain the spectrogram (Fig. 2). The line intensities then are obtained with a densitometer (Fig. 3). Standard solutions are run using the same procedure.

Working, or analysis, curves (Fig. 4) are made using the ratios of element line intensities versus the internal standard lithium spectral line. The ratios obtained from the samples then are plotted on these curves to obtain element concentrations.

The densitometer spectral line data are as follows:

- Internal standard lithium—2,741.3 a.u.*
- 1 to 10 ppm chromium—2,835.6 a.u.
- 10 to 100 ppm chromium—2,712.3 a.u.
- 1 to 10 ppm nickel—3,050.8 a.u.
- 10 to 100 ppm nickel—3,045.0 a.u.
- 1 to 100 ppm copper—2,618.4 a.u.
- 1 to 100 ppm zinc—3,282.3 a.u.

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*Angstrom units.

If concentration values are over 100 ppm, the samples are re-run using smaller samples and then multiplying by the appropriate factor. Other elements also can be looked for in the spectrum if so desired.

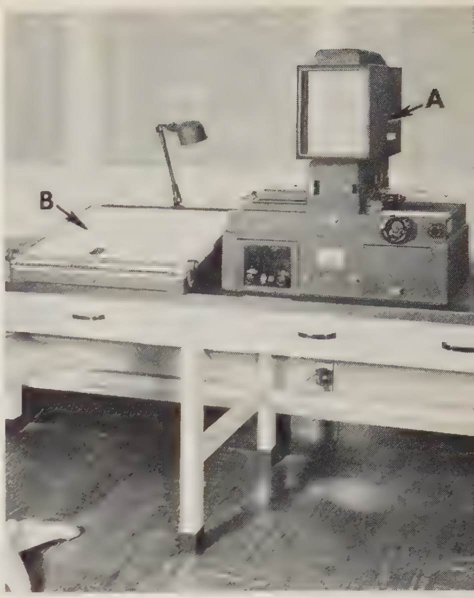
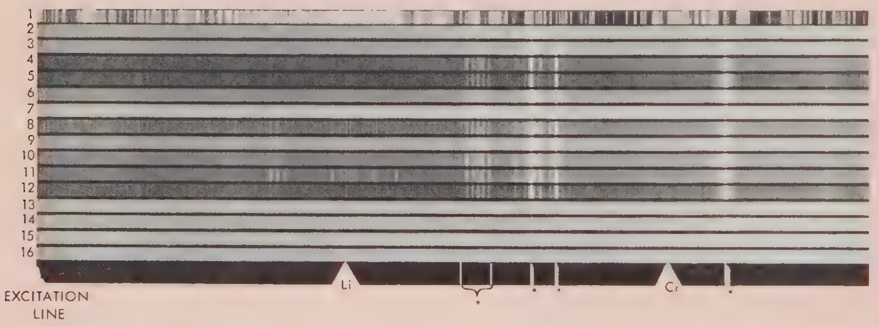


Fig. 3—An important instrument in a spectrograph laboratory is a densitometer, used for measuring the density of a spectral line as photographed on the spectrographic film. The GMC Engineering Chemical Laboratory uses a projection-type densitometer *A* with a built-in comparator which projects a magnified image of the spectrum of the sample being analyzed alongside a standard spectrum showing important spectral lines of the elements. Shown at the left of the densitometer is a calculating board *B*. This board, equipped with movable ordinate and abscissa logarithmic scales, is used to plot curves necessary to obtain information on the concentration of various elements in the sample being analyzed. It also is used to compute ratios which are needed to obtain the concentration in ppm of the elements sought.



1 . . . . IRON REFERENCE
2 – 12. EFFLUENT SAMPLES
13 . . . . STANDARD CHROMIUM – 1 PPM
14 . . . . STANDARD CHROMIUM – 5 PPM
15 . . . . STANDARD CHROMIUM – 10 PPM
16 . . . . STANDARD CHROMIUM – 15 PPM

* . . . . MAGNESIUM LINES

Fig. 2—This spectrogram, showing 16 excitations, is typical of those occurring in the analysis of effluent samples at GMC Truck and Coach Division. The spectral lines for the elements lithium (*Li*) and chromium (*Cr*) were of specific interest in this portion of the spectrum. The excitation line No. *1* at the top is for iron. This was placed on the film along with the other exposures by exciting a piece of cast iron. The characteristic spectral lines for iron always appear in the same location. The spectral lines for iron, of which there are many, have certain characteristic groupings which help to orientate the spectrographer in making the desired identifications. The spectral lines for iron also are on a master plate. When the two sets of iron spectral lines are placed in alignment, the location and identification of element lines becomes an easy matter, for the element lines also are on the master plate. It will be noted on this spectrogram that decreasing amounts of chromium (lines *13* through *16*) show a corresponding decrease in the intensity of the chromium line. Also, chromium is absent or nearly so in the effluent samples (lines *2* through *12*). When the lithium intensity appears in the normal intensities shown here, and the chromium line is absent, element determination is made by inspection. That is, the concentration of the element is reported as less than one part per million. There is no need to make a densitometer reading and working curve computation at this level of concentration.

The sample used for determining the concentration of the four metals cannot be used for investigating the presence of cyanide or oil or the pH value because of the acid added to the sample. Such information must be obtained by chemical procedures and requires a different sampling technique.

Stock solutions are made for copper, nickel, chromium, and zinc. Each solution represents a concentration of 100 ppm. These solutions are diluted again to produce various levels of concentration desired (Table I).

Effluent May be Analyzed for Presence of Many Metals

So far, copper, nickel, chromium, and zinc have been the four metals determined in the effluent samples. There is no reason why the presence of other metals cannot be determined, however, since the spectrogram shows all of the lines recorded. If other metals are present in the effluent, and it is desired to determine their magnitude, standard

STOCK SOLUTIONS

FOR COPPER: DISSOLVE 0.393 g OF $CuSO_4 \cdot 5H_2O$ AND DILUTE TO 1,000 ml WITH H_2O
FOR NICKEL: DISSOLVE 0.448 g OF $NiSO_4 \cdot 6H_2O$ AND DILUTE TO 1,000 ml WITH H_2O
FOR CHROMIUM: DISSOLVE 0.282 g OF $K_2Cr_2O_7$ AND DILUTE TO 1,000 ml WITH H_2O
FOR ZINC: DISSOLVE 0.455 g OF $Zn(NO_3)_2 \cdot 6H_2O$ AND DILUTE TO 1,000 ml WITH H_2O

STANDARD SOLUTIONS

STOCK SOLUTION (ml) +	H_2O (ml) =	PPM
1	99	1
5	95	5
10	90	10
25	75	25
50	50	50

Table I—Stock solutions are made for copper, nickel, chromium, and zinc using the procedure indicated at the top. Each solution represents 100 ppm. The stock solutions then are diluted to obtain the various levels of concentration desired by adding the amounts of H_2O shown at the right. The computations are based on a 100 ml sample of effluent.

solutions can be produced in a manner similar to the others.

Experience at GMC indicates that the following spectral lines would be good to start with if it is desired to know the presence of other metals in an effluent sample. Other spectral lines may be found to be more suitable.

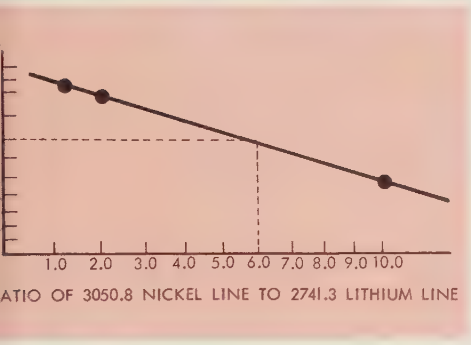


Fig. 4—This is a typical working curve developed during the analysis of effluent samples. The particular working curve shown here is for low concentrations of nickel, in parts per million (ppm), versus the ratio of the nickel element line and lithium line intensities. The intensity is measured in terms of transmittancy of each line. These lines, then, have a relationship which is called the ratio of their intensities.

To obtain a working curve a series of standard solutions is first analyzed. In fact, the standard solutions are analyzed many times to obtain consistent ratios for given values (concentration of elements present). These ratios versus the concentrations known to be present then are plotted using a calculating board (Fig. 3) to obtain the working curve. A table could be made using information from the working curve to show what ppm of element was present for the various ratios. The normal procedure, however, has been to take the ratios found in running submitted samples and then plot them on the working curve to find their respective values in ppm. For the working curve shown here, a ratio of 6.0 indicates that 3 ppm of nickel is present in the sample.

Aluminum	3,092.7 a.u.
Antimony	2,528.5 a.u.
Arsenic	2,349.8 a.u.
Barium	3,071.6 a.u.
Bismuth	3,067.7 a.u.
Boron	2,497.7 a.u.
Cadmium	3,466.2 a.u.
Cobalt	3,405.1 a.u.
Lead	2,833.1 a.u.
Magnesium	2,852.1 a.u.
Mercury	2,536.5 a.u.
Phosphorus	2,535.7 a.u.
Silver	3,280.7 a.u.
Sodium	3,302.3 a.u.
Tin	3,175.0 a.u.

Conclusion

The spectrochemical analysis method allows accurate information to be obtained on the concentration of metals in effluent samples six to seven times faster than that provided by the previously used method of straight chemical analysis. When the chemical analysis method was employed, a separate chemical procedure had to be used for each element to be determined. This required time for the preparation of separate samples, time for the preparation of reagents, time for filtrations or other means used to eliminate interfering elements, time for the reactions to take place, and time required for the handling of equipment.

Although the effluents have been checked so far for the presence of only four metals used in plating operations, the new method has the potential to determine the presence of many other metals at the same time and in the same effluent sample.

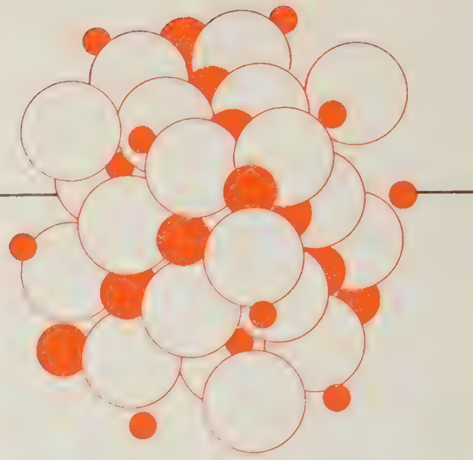
The accuracy of the spectrochemical analysis method is good in the few parts per million normally encountered. It probably would not be good for large concentrations of perhaps 200 ppm. The spectrographic analyses made so far show that the concentrations of chromium, nickel, copper, and zinc are well below the acceptable concentrations established by local municipal authorities. If a significant increase in the concentration values should occur as a result of an unknown change in the plating operations, immediate steps would be taken to correct the cause. If a significant concentration value should appear on the spectrogram and the question raised as to whether an interference of a spectral line from some other element had occurred, a check could be easily made by inspecting the other significant spectral lines given in the literature for the element being determined.

Some spectrographers might point out that a spark rather than a d-c arc would be more desirable for solution excitation. It should be mentioned that GMC chemists moved in the direction which they felt would give a fast, accurate, and economical method of analysis. Results to date have proven this line of thinking.

Acknowledgment

The author wishes to acknowledge the help of Gerard J. Jones of GMC Truck and Coach Division's Engineering Chemical Laboratory for his assistance in developing the spectrochemical method for analyzing effluent samples.

An Evaluation of Thermistors: Thermally Sensitive Semiconductors



The term *thermistor*, derived from *thermally sensitive resistor*, applies to a class of semiconductor materials having some particularly useful characteristics for control and measuring devices. Like most other materials, the electrical properties of thermistors change with changes in temperature, but the way in which these properties change is the key to their value as control and measuring devices. For example, thermistors have a time delay characteristic, they have a static volt-ampere characteristic, and their resistivity decreases as temperature increases. Their principal advantage over metallic conductors is a much higher sensitivity to variations in temperature. The present state of knowledge of thermistors is far from complete, however. Continuing research in the electro-ceramic field, which produces thermistor materials, and in the solid state physics field may provide answers to some of the present questions involving composition and processing.

NOT LONG AGO, the term *semiconductor* referred to experiments in which an electroscope was discharged by means of a wooden rod or a wet string. At that time poor conductors of any kind were called semiconductors. Today, however, there is extensive knowledge of a class of materials which can be more accurately called semiconductors.

Broadly defined, semiconductors are pure electronic conductors of electricity having a resistivity at room temperature between 1 ohm-cm and 10^{10} ohm-cm. Semiconductors that have a thermally variable resistivity are known by the abbreviated term, *thermistors*.

Many substances fit the definition of a thermistor and they have been investigated extensively in research directed toward the development of semiconductors. Only a few substances, however, possess the desired characteristics for practical thermistor application.

Two elements, germanium and silicon, were commonly used during World War II as high frequency rectifiers and have since formed the background for the transistor industry. Another element, selenium, is the main component in power rectifiers. In compounds, the oxides are widely used, especially copper oxides, iron oxides, manganese oxides, nickel and cobalt oxide, titanium oxide, and uranium oxide. Among other compounds, silver chloride, copper sulfide, and silicon carbide are used.

How Electro-Ceramics Are Used In Thermistor Production

The use of oxides of the transition metals or combinations thereof has been particularly advantageous in the production of thermistors, which are now an important segment of the growing electro-ceramics field.

Ceramics have been used almost from the beginning of the electrical industry. Porcelain, a product developed by the Chinese over a thousand years ago, was soon recognized as an excellent insulator and is still used, for example, in the insulation of high tension lines.

In addition to insulators, materials now classified as electro-ceramics include semiconductors, dielectrics, and both "soft" and "hard" ferromagnetics. The manufacturing processes of these ceramic bodies such as milling, molding, calcining, firing, and sintering, generally resemble the techniques employed in the more common branches of the ceramic

ELECTRO-CERAMICS

SUBSTANCE	STRUCTURE	TYPICAL PROPERTY OR APPLICATION
SrO BaO NiO	SODIUM CHLORIDE	OXIDE-COATED CATHODES
α-Al_2O_3 α-Fe_2O_3	α-CORUNDUM	INSULATOR
BeO	WURTZITE	INSULATOR
TiO_2	RUTILE	DIELECTRIC
ZnO SiC	WURTZITE	SEMICONDUCTOR
Fe_3O_4 $(Mn\ Zn)\ Fe_2O_4$	SPINEL	SEMICONDUCTORS, FERROMAGNETICS
Mg_2TiO_3	SPINEL	DIELECTRIC
$BaTiO_3$ $LaMnO_3$	PEROVSKITE	DIELECTRIC SEMICONDUCTOR
$BaFe_{12}O_{19}$	MAGNETO PLUMBITE	FERROMAGNETIC PERMANENT MAGNETS

Table I—This table lists some of the electro-ceramics whose physical and chemical properties are independent of the polycrystalline nature of the material. A number of them are oxides of the transition metals. While these substances have useful characteristics, a more valuable product often is obtained when certain metal ions are partially replaced by others. For this reason, it is important to know the crystallographic structure of the compounds, regardless of their polycrystalline condition.

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From the growing field of electro-ceramics, highly sensitive devices

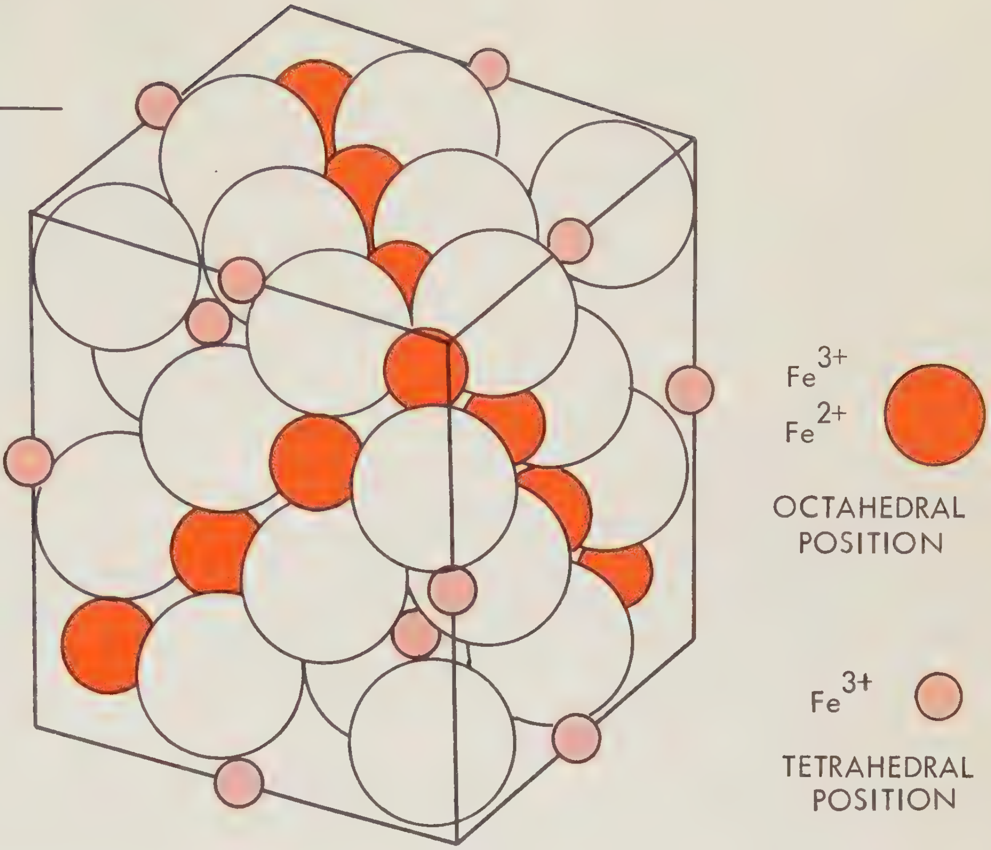

Fig. 1—The diagram at the right shows the formation of iron ferrite, or magnetite, in the spinel lattice form. It consists of a regular cubic close packing of oxygen ions with two tetrahedral interstices for every octahedral interstice per unit cell of the lattice. In Fe_3O_4 there are two Fe^{3+} ions for every Fe^{2+} ion. From electrical and magnetic data it has been established that the octahedral positions are occupied by both Fe^{3+} and Fe^{2+} ions while only Fe^{3+} ions occupy the tetrahedral sites.

industry. It is sometimes desirable, however, to add organic plasticizers or binders to the ground raw materials to make a suitable molding possible. These binders are usually evaporated or burned out during the firing or sintering processes.

Many ceramics contain silicates and consist of various chemical phases. In electrical technology, however, interest is usually focused on one significant physical property and often such a property is most clearly demonstrated in a single crystal of a particular compound. In most cases it is difficult and often unnecessary to produce single crystals. The production of ceramic monophase systems is helpful since it may offer the advantage of being relatively easy to form.

In many respects the physical and chemical properties of ceramics are independent of the polycrystalline nature of the material (Table I). An example is the type of structure possessed by the ferrite semiconductors. Iron ferrite, or magnetite, crystalizes in the spinel lattice form (Fig. 1). The name *spinel* was originally given to a mineral having the formula $MgAl_2O_4$ but a large number of compounds, notably Fe_3O_2, have the same structure.

Electron Movement Key To Semiconductor Action

To understand the action of a thermistor, it is important first to consider the simplest aspect of electrical conduction in a semiconductor—that of a single, isolated, free atom. The electrons of the atom fill discrete energy levels with "forbidden" gaps in between. When an electric field, acting on an electron, has the correct magnitude it causes the electron to jump to an unoccupied level.

A similar situation exists for electrons moving between the atoms in the lattice structure of a solid body. In a solid, every atom has its own energy levels, but here they appear as broad bands because of the strong interactions between the closely spaced atoms. There also are forbidden or empty gaps between the bands. Under the influence of an applied field, the motion of electrons in solids can be visualized as the motion of electrons in the bands if there are empty levels. Furthermore, after jumping from one band to another there can be motion in the new band.

In an insulator all bands are either completely filled with electrons or completely empty so that the electrons cannot move. The crystal, therefore, cannot carry any current. In a metal it is presumed that the uppermost band which contains electrons is only partly filled.

In this band there are many empty levels adjacent to the highest occupied levels. An applied electric field easily raises the electrons into the empty levels and produces conduction.

If foreign atoms are added to an insulator or if the atoms are distorted in any other way, new electronic levels will be introduced in the forbidden regions. When these new impurity levels are occupied by electrons, these electrons may be thermally excited to the empty band and the substance is an electronic semiconductor. If the level is unoccupied, it can accept electrons thermally excited to it from the filled band leaving vacancies, or "holes," in the previously filled band. In the latter event the substance becomes a "hole" semiconductor.

A semiconductor at 0° absolute temperature is in the same situation as a normal insulator. But as the temperature increases some electrons jump into the lowest empty band of allowed levels (conduction band) and the substance becomes conductive.

Semiconduction Divided Into Intrinsic, Extrinsic Types

Two types of semiconduction may be distinguished—intrinsic and extrinsic. Both may occur, however, in the same substance.

Intrinsic Semiconductor

An intrinsic semiconductor conducts electricity in the pure state. The band structure is similar to that found in insulators except that the energy gap between the highest filled band and the lowest empty band is relatively small, permitting thermal excitation of electrons at moderate temperatures.

Silicon and germanium, for instance, exhibit intrinsic conduction at higher temperatures. Magnetite is almost unique among the metal oxides in behaving as an intrinsic semiconductor at moderate temperatures. Its high conductivity can be attributed to three factors:

(a) *Fe* ions of differing valency in the same lattice site act as "foreign" atoms to create new energy levels in the lattice

(b) Electron exchange is particularly favorable between ions of the same element

(c) Electron exchange is particularly favorable between ions differing in valence by only one.

Extrinsic Semiconductor

Most semiconductors, however, belong to the extrinsic type. They owe their conductivity to the presence of impurities in solid solution or to lattice imperfections. The actual value of the conductivity is very sensitive to the amount of these irregularities. These irregularities are responsible for the extra energy levels appearing in the normally forbidden region between a filled band and an empty band, and greatly reducing the energy required to bring an electron into the conduction band. Zinc oxide and titanium dioxide are typical extrinsic semiconductors in which the current is carried by thermally excited electrons. Typical vacancy or hole extrinsic semiconductors are uranium dioxide and cuprous oxide.

Thermistor Characteristics Permit Numerous Applications

If the resistance of a semiconductor is measured at different temperatures with the current being so small as not to heat the body materially, it is found that the resistance decreases with increasing temperature and that the logarithm of the resistance R plotted against the inverse absolute temperature T follows a straight line over rather wide temperature limits. Therefore,

$$\log R = A + \frac{b}{T}$$

where A and b are constants.

If

$$A = \log a,$$

then the relation

$$R = ae^{c}$$

where

$$c = -\frac{b}{T}$$

is correct as long as the effect of temperature on a can be neglected.

The temperature coefficient of resistance is defined as

$$\alpha = \frac{1}{R}\frac{dR}{dT}.$$

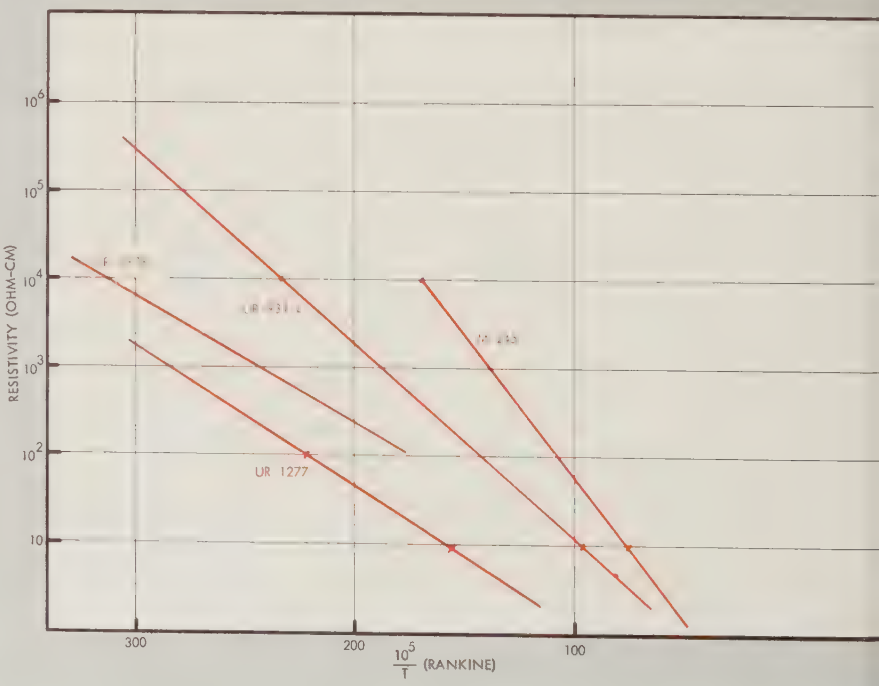

Fig. 2—These curves represent the temperature-resistance of four thermistor compositions. They show the wide range of resistivities and temperature coefficient of resistance which are obtained from a single substance—magnetite. The curves are identified by their assigned laboratory number.

This can be transformed into

$$\alpha = \frac{-b}{T^2}$$

which means that not only the resistance but also the temperature coefficient of the resistance decreases rapidly with increase in temperature. The temperature coefficient of semiconductors can be varied between wide limits from almost zero to about 10 per cent per degree change in temperature.

Recently, semiconductors of the thermistor type have become useful in many branches of industry and science as measurement and control devices. Three physical characteristics which make thermistors valuable in these areas are:

- Variation of resistance with temperature
- Static volt-ampere characteristic
- Time delay action.

At AC Spark Plug Division, each of these characteristics has been studied to determine its best application.

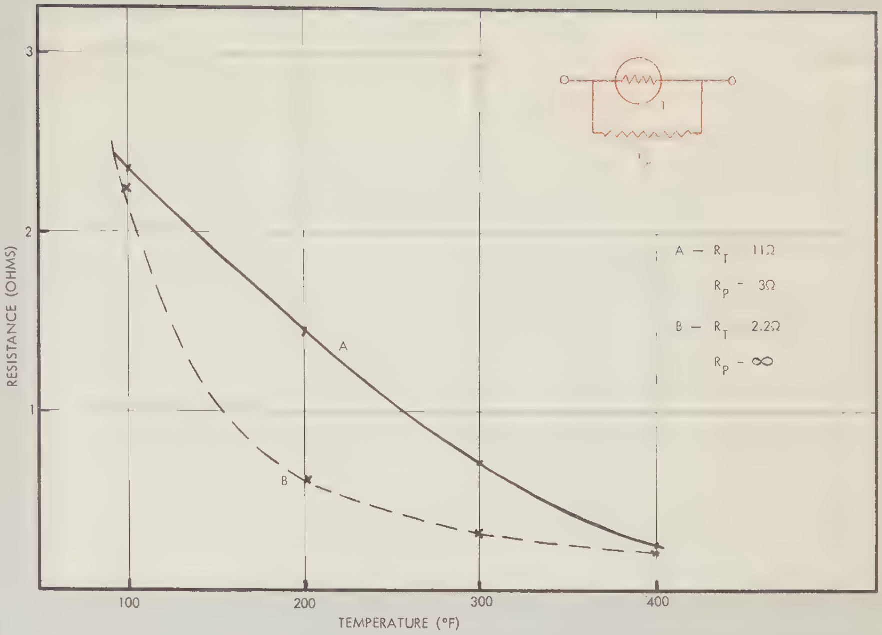

Fig. 4—In the above graph, curve *A* shows the extreme non-linearity of the temperature-resistance relationship of a thermistor used by itself. Curve *B* shows the same relationship when a thermistor of higher resistance is used paralleled with a conventional ohmic resistance as illustrated in the circuit inset. This application achieves a good linear resistance change between the endpoints 100°F and 400°F.

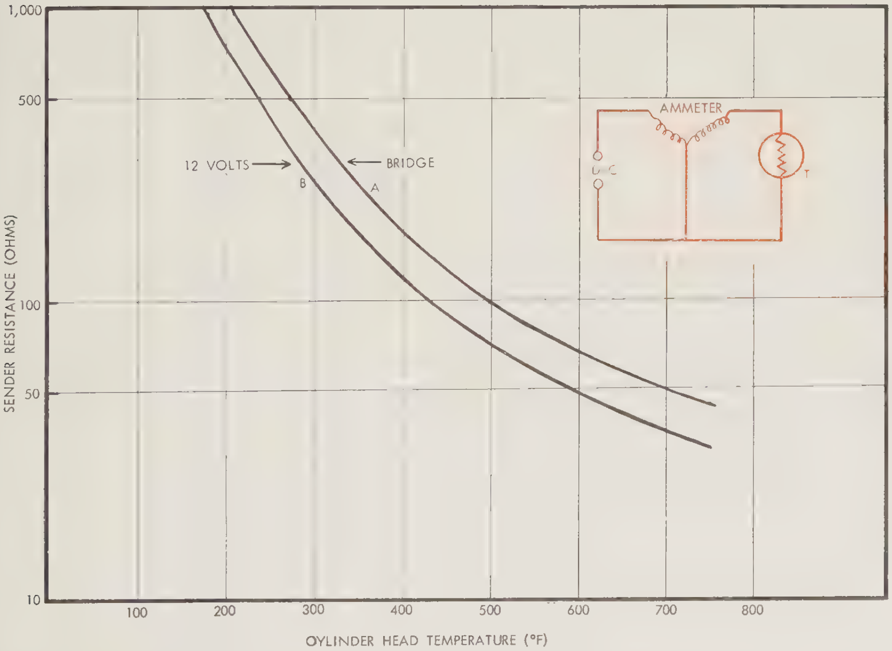

Fig. 3—Performance characteristics of a typical electric cylinder head thermogage are plotted in this graph. Curve *A* represents the true temperature resistance curve of the thermistor since the resistance is measured by a Wheatstone bridge which does not perceptibly heat the thermistor and, therefore, gives the actual thermistor temperature. Curve *B* illustrates the typical service performance in an electrical system. The milliammeter used to obtain this reading requires current values that appreciably heat the thermistor so that it is always at a higher temperature than the ambient it is measuring over the entire calibration range. This self-heating must be controlled by careful design so it does not cause overheating and, consequently, poor sensitivity at high temperatures. The inset shows the cylinder head thermogage circuit.

Variation of Resistance with Temperature

In metals, resistance increases as temperature increases. In the thermistor, the resistance goes down as temperature goes up. The distinguishing advantage of semiconductor materials over metallic conductors as measuring devices is a much higher sensitivity. This sensitivity is due to three important features:

- Absolute value of the resistivity can be adapted to a wide range of many magnitudes in special circuit conditions
- Temperature coefficient of resistance can be adapted to special requirements
- Temperature coefficients of thermistors can be made higher than that of metals.

Ceramic techniques are particularly important in establishing the electrical characteristics and stability of a thermistor composition. Close supervision of particle size distribution and mineralogical form of the starting materials, bonding and fluxing additives, forming

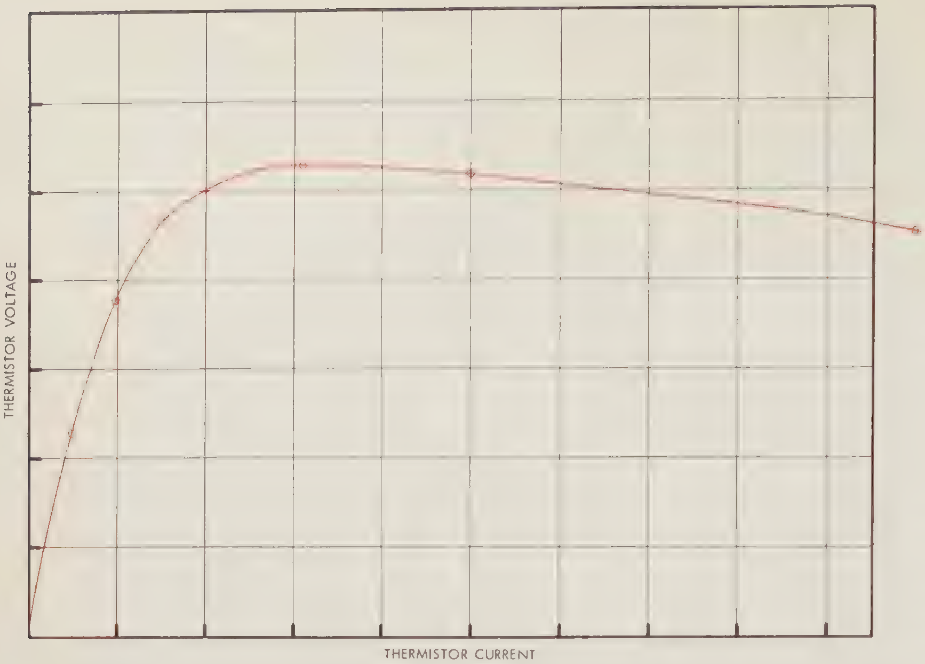

Fig. 5—The decrease in a thermistor's resistance as voltage is increased is illustrated here. The position of the peak can be moved in either direction by changing the geometry of the thermistor or its thermal contact with its surroundings. Notice that to the right of the peak the voltage drops monotonically with increasing current. The thermistor behaves as a negative resistance in this region and thus, could, in principle, be used to construct a low frequency oscillator.

pressures, sintering times, atmospheres, and temperatures are necessary if a controlled product is desired (Fig. 2).

One of the principal applications of thermistors has been in temperature measurement. Thermistors have been made for use in the familiar electric thermogages which indicate the engine coolant temperature in several makes of cars. It would appear that for such an application the material with the largest temperature coefficient of resistance would be chosen in order to obtain maximum sensitivity. In practice, however, this is not desirable where any extended range of temperature is to be covered. A thermistor with a very high temperature coefficient may show such a large change in resistance over a temperature range of 200° to 400° F that a moderately priced current indicating meter will not have a satisfactory calibration over this range (Fig. 3).

Another application of the high negative temperature coefficient of resistance of thermistors is in the field of temperature compensation. As shown in Fig. 2, all semiconductors display the same functional relationship between resistance and temperature. All of the curves in Fig. 2 are straight lines. Only the slope, not the form of the curves, can be varied. While this, of course, limits the usefulness of the thermistor by itself for temperature compensation, it has been found that by synthesizing a simple network of a thermistor and an ohmic resistor, considerable versatility can be obtained (Fig. 4).

Static Volt-Ampere Characteristic

At a constant ambient temperature, a thermistor obeys Ohm's Law at very low applied voltage. As the voltage increases the thermistor begins to heat up and its resistance decreases. A point is eventually reached at which the rapid heating limits the value of the applied voltage (Fig. 5). After the peak voltage is reached, the voltage drops with increasing current, behaving as a negative resistance.

Time Delay

When a thermistor is cold it has a high resistance which may be several powers of ten higher than the thermal equilibrium resistance which the thermistor may reach sometime after the voltage is applied (Fig. 6). This behavior can be used either for surge protection or for automatic switch control. In the first case it protects a unit of an electric circuit when too much power is initially applied. For example, the voltage drop of an electrical lamp system is low until the tungsten filaments are hot. When placed in series with the lamp system the thermistor, which has an inverse temperature coefficient of resistance, is beneficial because it has a large voltage drop due to its high initial resistance. Many small table model or portable

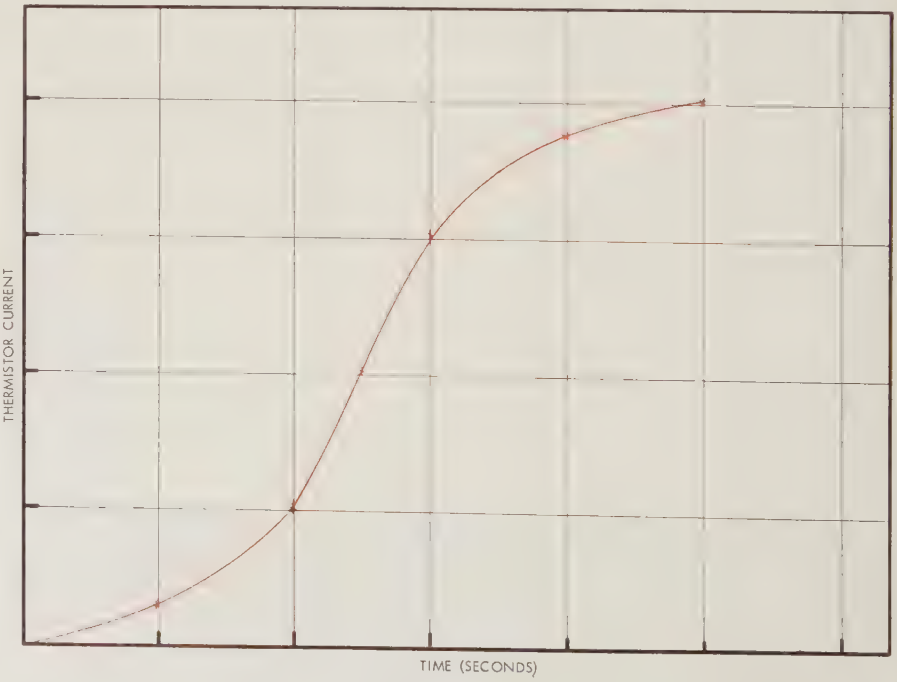

Fig. 6—When voltage is suddenly applied to a thermistor, the current flow follows the course plotted here.

radios using series string filaments use a thermistor in series with the power supply to prevent possible damage to individual tubes when the power is suddenly applied.

A thermistor also can be used as an automatic control when it is desirable to delay opening a valve or actuating a circuit for an operational or a safety reason. It may be desirable in an oil burner, for example, to delay the opening of the valve for a few seconds after the burner controls are activated. This delay can be accomplished by placing a thermistor in series with the valve solenoid winding (Fig. 7).

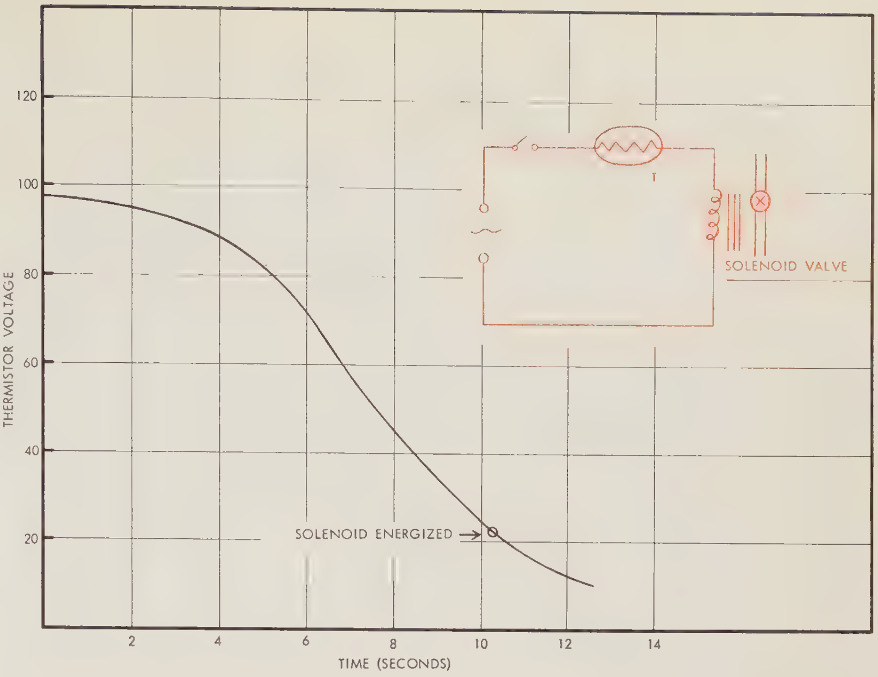

Fig. 7—This curve shows the time delay characteristic of a thermistor placed in series with a valve solenoid winding in an oil burner. When the voltage is first applied, the thermistor has such a high resistance that most of the voltage drop in the circuit is across the thermistor. As the thermistor heats up, the voltage across it decreases at a rate dependent on its size and heat transfer characteristics. Shortly after 10 seconds of applied voltage, the thermistor is passing enough current to actuate the solenoid and to open the valve.

Further Development Depends On Research in Physics, Ceramics

Present knowledge in the thermistor field is still incomplete. Some types of thermistors are fairly well understood while others are not. The general model discussed in this paper is a satisfactory one but more work remains to be done on the peculiarities of the electrical conductivity in each different substance.

The current literature suggests that solid state physics has progressed to the point where it is possible to make a quantitative comparison of calculated and measured values of conductivity in various substances. If this is successful, it may be possible to predict especially favorable thermistor systems and to predict the effect of various oxide combinations or of the addition of foreign ions to a pure oxide lattice.

Future developments in thermistors will probably be concerned with the following areas:

- Higher temperature coefficients of resistance
- Improved stability and chemical resistance
- Positive temperature coefficients over limited but controllable temperature ranges
- Better methods of making electrical contacts to thermistors.

From a practical standpoint further development depends heavily on corresponding developments in the ceramic field. To produce a satisfactory end product, composition and processing cannot be separated. Ceramic research must learn more about the importance and control of such factors as:

- Mineralogical form and chemical combination of starting materials
- Raw material purity
- Calcination or other heat treatment
- Particle size distribution and control
- Effects of binders and fluxes
- Forming processes
- Sintering time and temperature relations
- Sintering atmospheres
- Crystallographic structure of the end product.

Conclusion

Thermistors have advantages over thermocouples but so far they have been somewhat lacking in electrical and structural stability at high temperatures. Progress is being made toward improvements in these areas. When scientists obtain more knowledge and experience regarding thermistor composition and processing, the thermistor should be able to successfully invade the field of high temperature measurement, a field in which thermocouples are presently almost universally used.

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Applying a Digital Computer to Study the Frequency Response of a Transistor Audio Amplifier

Engineers outside the electronics field have shown a stronger inclination to use digital computers to solve engineering problems than electronics engineers. This might be due to the fact that an electronic circuit is basically an analog computer and, therefore, electronic engineers have developed a greater "feel" for the analog approach in problem solving. At Delco Radio Division, however, a digital computer now is applied by engineers to study the gain versus frequency of a transistor audio amplifier used in the output stage of an automobile receiver and to investigate how a change in certain parameters affects the overall gain and response of the stage. This work is accomplished by first preparing an equivalent a-c circuit of the audio stage as a model for mathematical analysis. By applying Kirchhoff's voltage law, five simultaneous equations in five unknowns are obtained. These equations are then solved through use of a digital computer for each of several frequencies to determine their gain-frequency characteristics. The results obtained indicate that a digital computer also might be used to investigate other programs where the input consists of performance specifications.

The use of digital computers as an aid in solving engineering problems is becoming a widely accepted practice. The advantages obtained in using this electronic device, however, are being exploited more effectively by engineers outside the electronics field. The few applications of digital computers to electronic circuit design found in the literature[1,2] refer to switching and timing circuits where transistors or tubes are alternately biased at cutoff and saturation—definitely not audio applications.

One explanation for the relative lag in the application of digital computers to electronic design may be the fact that an electronic circuit is itself essentially an analog computer. A large quantity of data can be obtained on many parameters quickly and inexpensively by merely twisting the knobs on a group of decade boxes. In a mechanical problem, however, more time and expense is usually involved in changing the mass, compliance, or damping of a dynamic system.

A mathematical treatment of the equivalent network of an electronic circuit produces large systems of simultaneous equations with complex frequency dependent coefficients which often require days instead of minutes to solve by hand calculation. As a result, the average electronics engineer has developed a "feel" for the analog approach and has all but forgotten the classical methods of analysis.

The ready facility of digital computers to perform innumerable arithmetic operations at a high speed and without mistakes now makes it feasible to solve large systems of equations. Matrix algebra, therefore, can be profitably revived from a theoretical science to a useful engineering tool, enabling audio engineers to return to more accurate and classical methods of analysis.

An example of this is the use of a digital computer by Delco Radio Division engineers to calculate the gain-frequency characteristic of a multi-mesh transistorized amplifier. The computer also permits an investigation of the effect varying the parameters has on the overall gain response of the amplifier.

Automotive styling requirements result in various acoustic load characteristics presented to the loudspeaker[3]. The frequency response of the receiver as well as the loudspeaker must be carefully tailored to insure the proper tone balance for a high quality automobile receiver. Most of the tailoring of the audio response of the receiver is performed in the audio stages.

The design objective for the portion of the audio amplifier from the driver grid to the load is generally a response as flat as possible in the bass and middle ranges with a suitable rolloff of the high response to suppress electrical noise and adjacent channel interference on the AM band.

First Step—Develop an Equivalent Circuit for Audio Output Stage

The first step taken by Delco Radio engineers in investigating this problem was to draw an equivalent a-c circuit of the audio stage to provide a model for mathematical analysis. They also had to decide how exact an equivalent circuit should be (Fig. 1). In hand calculations many approximations are usually made to simplify calculations. Once the program is prepared on a digital computer, however, an exact solution can be calculated almost as rapidly as an approximate one. Factors which obviously have negligible effect on performance, such as distributed capacitances, are eliminated to simplify programming.

Using the method of loop analysis involving the repeated application of Kirchhoff's voltage law, five simultaneous equations in five unknowns were obtained (Fig. 2). Since the analysis of the volume control with its tone compensation re-

Fig. 1—The diagram at the top is a schematic di
gram of a typical audio amplifier. A Delco DS5
power transistor is used in a transformer coupl
common emitter circuit. The driver in this case is
low voltage tube used in hybrid auto receivers. T
diagram at the bottom is the equivalent circuit
the amplifier. This was drawn to provide a model f
mathematical analysis. A five mesh network is r
quired to represent the amplifier. Since the chara
teristics of the driver tube are similar to those of
triode, an equivalent constant voltage generator
used to represent the source. The constant curre
generator type equivalent circuit is used to represe
the transistor[4]. In the equivalent circuit of the tran
formers, the distributed capacitances, coupling capa
itance, hysteresis, and eddy current losses a
neglected. The problem is further simplified
substituting a resistance load for the electrical anal
of the loudspeaker load. The circuit has 16 param
eters which can be varied to obtain the desir
performances.

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Division

Computer permits
exact instead of
approximate solutions

quires three more meshes, it was treated in a separate program.

Since practically all the coefficients in the five equations derived from the network are frequency dependent, the equations must be solved for each of several frequencies required to describe adequately the gain-frequency characteristics. This is the task made possible by a digital computer.

$$\text{(1.)}\quad \frac{(\mu+1)R_K+R_p+R_{pd}+j\omega L_{pd}}{n_d^2}\, i_1 - \frac{j\omega L_{pd}}{n_d^2}\, i_2 = \frac{\mu e_g}{n_d}$$

$$\text{(2.)}\quad -j\frac{\omega L_{pd}}{n_d^2}\, i_1 + \left[j\frac{\omega L_{pd}}{n_d^2} + j\omega L_{sd} + R_{sd} + R_B + (1+\beta_f)R_E\right] i_2 = 0$$

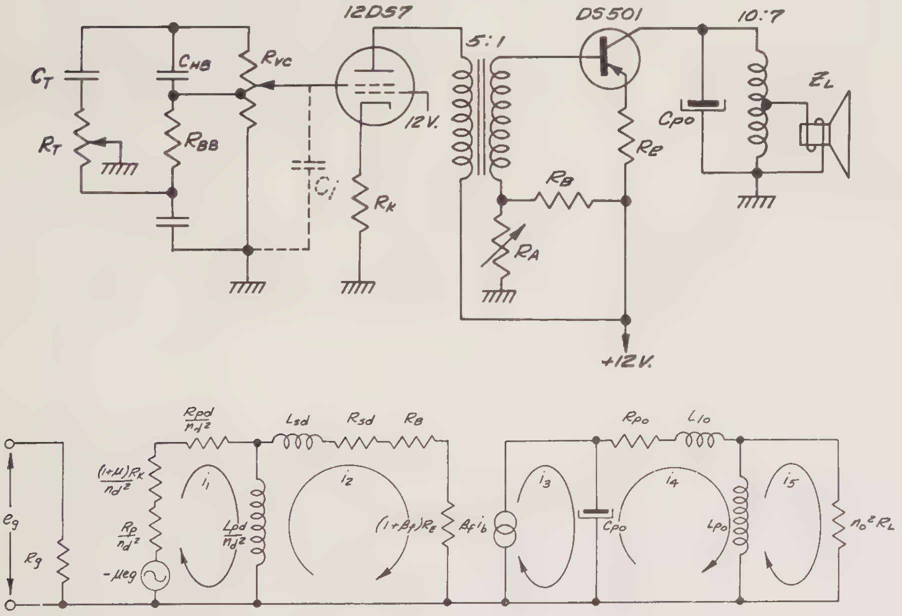
$$\text{(3.)}\quad \beta i_2 - 1 i_3 = 0$$

$$\text{(4.)}\quad \frac{-1}{j\omega C_{po}}\, i_3 + \left[\frac{1}{j\omega C_{po}} + R_{po} + j\omega(L_{lo}+L_{po})\right] i_4 - j\omega L_{po}\, i_5 = 0$$

$$\text{(5.)}\quad -j\omega L_{po}\, i_4 + (j\omega L_{po} + n^2 R_L)\, i_5 = 0$$

$$G = \frac{P_o}{P_i} = \frac{i_5^2 n_o^2 R_L R_g}{e_g^2}$$

Fig. 2—The five equations derived from the network are shown here along with the equation for overall gain of the stage. The five equations must be solved simultaneously to obtain i_5 in terms of e_g to obtain the overall transfer function of the amplifier.



R_g - GRID RESISTOR
R_p - PLATE RESISTANCE
R_K - CATHODE RESISTOR
R_{pd} - PRI. RES. - DRIVER TRANS.
L_{pd} - PRI. INDUCTANCE - DRIVER TRANS.
L_{ld} - LEAKAGE IND. - DRIVER TRANS.
n_d - TURNS RATIO - DRIVER TRANS.
n_o - TURNS RATIO - OUTPUT TRANS.
R_{sd} - SEC. RES. - DRIVER TRANS.
R_B - BASE RESISTOR
R_E - EMITTER RESISTANCE (INTERNAL ∮ EXTERNAL)
β_f - LARGE SIGNAL CURRENT GAIN AT FREQUENCY (f.)
C_{po} - OUTPUT PAD
R_{po} - PRI. RES - OUTPUT TRANS.
L_{po} - PRI. IND. - OUTPUT TRANS.
L_{lo} - LEAKAGE IND. - OUTPUT TRANS.
R_L - LOAD RESISTANCE

Manufacturers of electronic digital computers have machine programs available for the solutions of systems of simultaneous equations. Most of these prepared programs, however, require extra attachments to a medium speed basic computer such as a machine floating decimal and an index register. If this equipment is not available, a general equation for i_5 in terms of e_g, the voltage at the grid, can be derived by first solving the simultaneous equations by hand calculation using symbols for the coefficients (Fig. 3).

Substituting the original coefficients of the simultaneous equations produces the equation for i_5 (Fig. 4). After collecting real and imaginary terms, the equation is programmed in the computer to be solved at 18 frequencies across the audio band for each set of circuit values. The program then calls for the solution of the gain equation which gives the overall gain of the stage in decibels:

$$G_{db} = (10)\log_{10}\frac{(i_5^2)\,(N_o^2)\,(R_L)\,(R_g)}{e_g^2}$$

where

N_o = turns ratio of output transformer
R_L = load resistance
R_g = grid resistor
e_g = voltage at grid.

① $$A_1 i_1 + B_1 i_2 + 0 i_3 + 0 i_4 + 0 i_5 = K_1$$

② $$A_2 i_1 + B_2 i_2 + 0 i_3 + 0 i_4 + 0 i_5 = 0$$

③ $$0 i_1 + B_3 i_2 - 1 i_3 + 0 i_4 + 0 i_5 = 0$$

④ $$0 i_1 + 0 i_2 + C_4 i_3 + D_4 i_4 + E_5 i_5 = 0$$

⑤ $$0 i_1 + 0 i_2 + 0 i_3 + D_5 i_4 + E_5 i_5 = 0$$

$$i_5 = \frac{A_2 B_3 C_4 D_5 K_1}{(A_1 B_2 - A B_1)(D_5 E_4 - D_4 E_5)}$$

Fig. 3—Shown here are the five simultaneous equations used in deriving a general equation for i_5. The matrix form for i_5 is solved by use of determinates, producing the equation shown on the last line.

A table of logarithms to the base 10 is stored in the computer's memory unit for use in converting the input-output power ratio into gain in decibels.

The effects of variation of transistor, driver transformer, and output transformer characteristics are quickly determined by the use of this computer program (Figs. 5 through 10).

Results Indicate Method Has Other Applications

In this computer program the standard design technique is accelerated because of the high speed programmed computation provided. This program also indicates the possibilities of more sophisticated programs where the input consists of the performance specifications—in this case the desired frequency-gain characteristic. The computer then can be programmed to scan the circuit parameters and to search out automatically all possible combinations which will produce the required performance. These combinations can be studied for other characteristics such as linearity, power handling, and cost. A few minutes of calculating time can produce a detailed analysis which otherwise would require months of laboratory work.

The present program, of course, does not represent a complete analysis of the audio stage. Such characteristics as harmonic and intermodulation distortion versus power output can best be determined by measurement on a breadboard. It illustrates, however, that there are many parameters that now can be analyzed faster by a digital computer and indicates some of the possibilities of this new tool to the audio engineer.

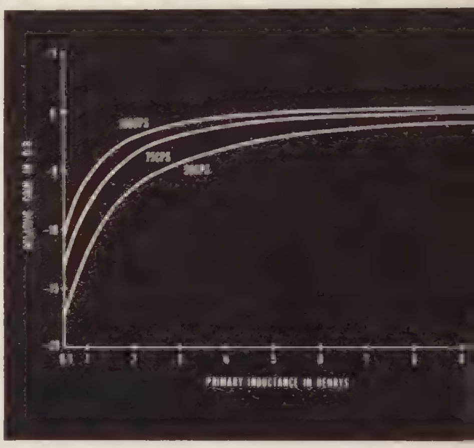


Fig. 5—This is a family of curves showing stage gain versus driver transformer primary inductances at low frequencies. The data indicate the optimum range of values from a cost-performance standpoint. Diminishing returns in stage gain are found above a primary inductance of six henries while below two henries a small reduction in cost is accompanied by a large reduction in performance.

Fig. 4—This is the complicated equation produced when the original coefficients of the simultaneous equations are substituted for the symbols shown in Fig. 3. The gain equation is solved for 18 different frequencies ranging from 50 cps to 12,000 cps.

$$\frac{\left(\frac{\mu e_g}{n_d}\right)\left(\frac{j\omega L_{pd}+L_{po}}{n_d^2 C_{po}}\right)\left(\frac{\beta_m}{1+jf/f_{\beta c}}\right)}{\frac{p+R_k(\mu+1)+R_{pd}+j\omega L_{pd}}{n_d^2}\left[j\omega\left(\frac{L_{pd}}{n_d^2}+L_{sd}\right)+R_{sd}+R_b+\left(1+\frac{\beta_m}{1+Kf^2}\right)R_e\right]+\frac{\omega^2 L_{pd}^2}{n_d^4}\Big\}\Big\{-\omega^2 L_{po}^2-\left[j\left(\omega L_{po}+\omega L_{lo}-\frac{1}{\omega C_{po}}\right)+R_{po}\right]\left(j\omega L_{po}+n_o^2 R_L\right)\Big\}}$$

$$G_{db} = 10\log_{10}\frac{P_o}{P_{in}} = 10\log_{10}\frac{i_5^2 n_o^2 R_L R_g}{e_g^2}$$

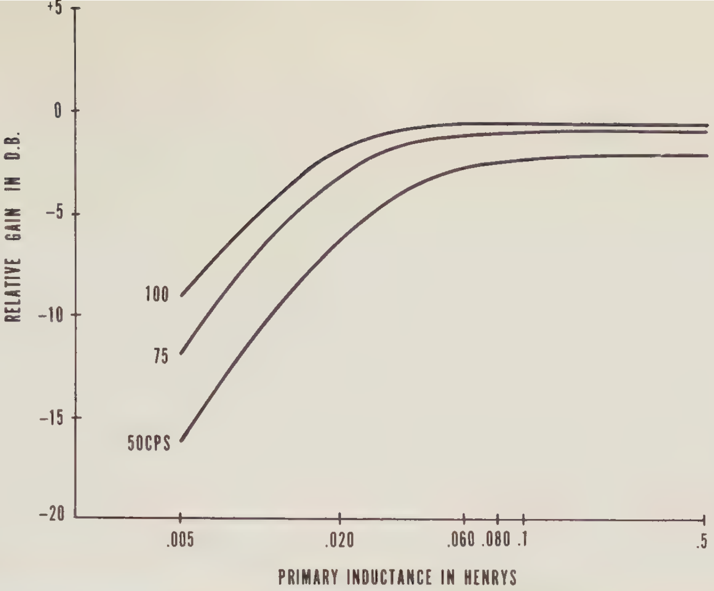


Fig. 6—This family of curves, similar to the curves shown in Figure 5, shows stage gain at low frequencies versus primary inductance of the output transformer which can be used to select the correct value for the performance required.

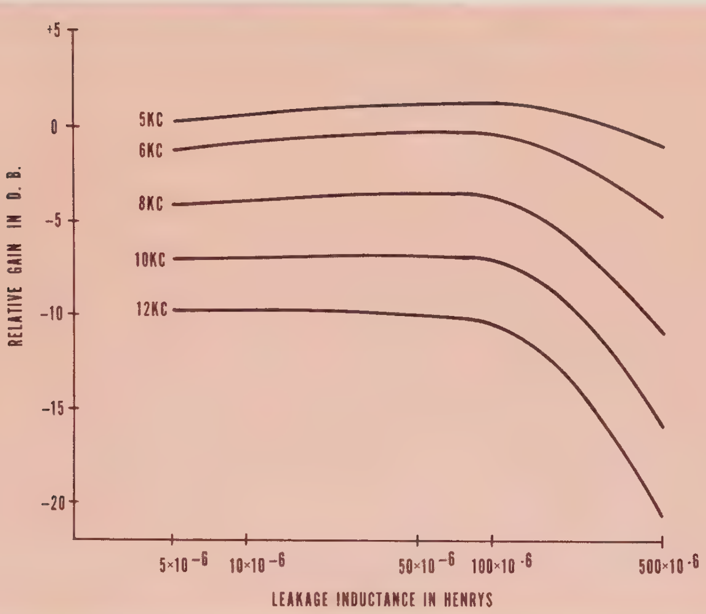


Fig. 7—A study of stage gain versus leakage inductance of the output transformer at high frequencies produced this family of curves. It showed the response rise caused by resonance between the leakage inductance and the output pad. The curves indicate that a wide range of leakage inductances can be tolerated over the frequency range of interest in AM receivers.

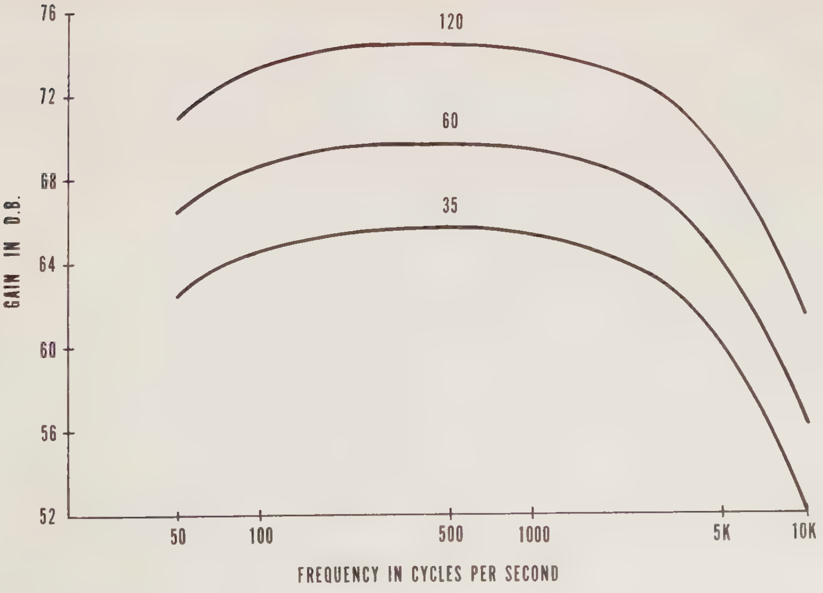


Fig. 8—This diagram shows a family of overall response curves using a range of transistor current gains. It shows that the transistor has a negligible effect on tone balance in the circuit under consideration and primarily affects the stage gain.

Fig. 9—A family of overall response curves using various values of the output pad is shown at the left. The curves at the right shows the calculated overall response of the amplifier using a set of desired values compared to the measured response on the actual circuit using the same set of values. The calculated and measured response show close agreement throughout the audio range.

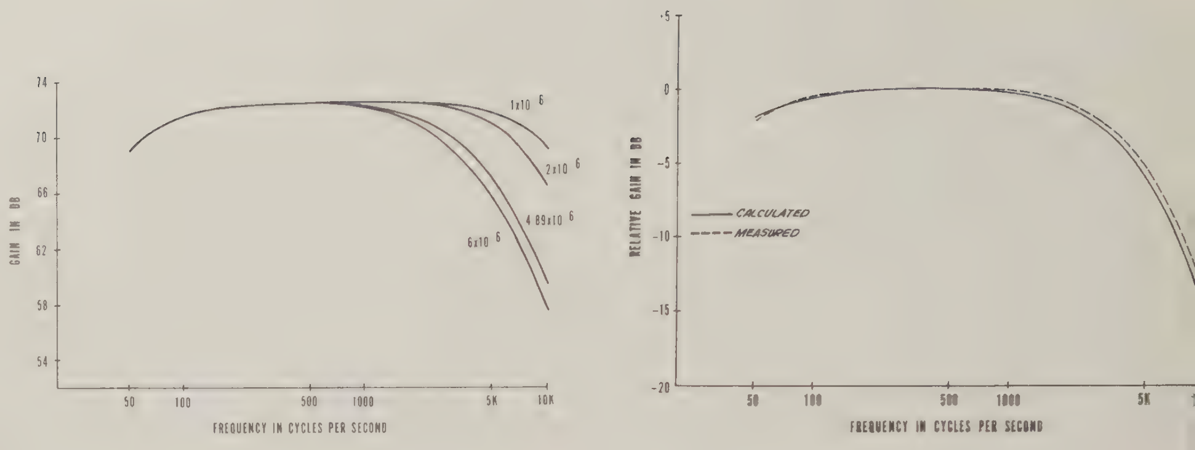
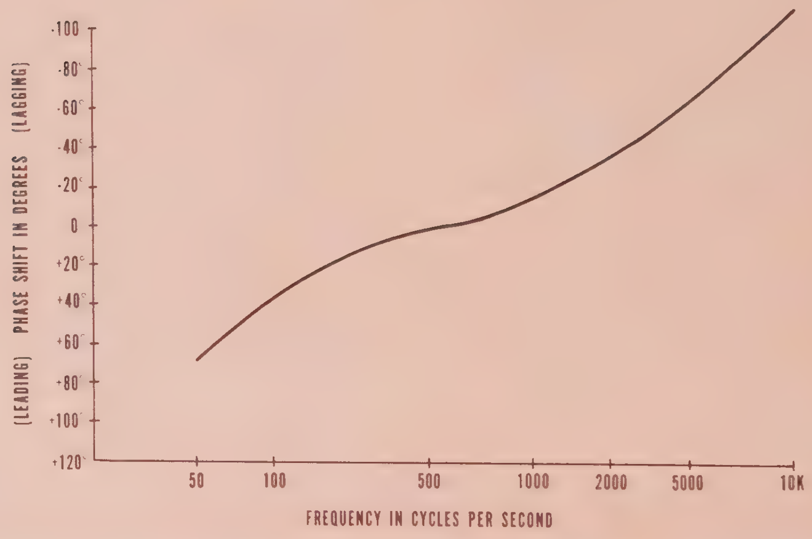


Fig. 10—The phase shift of the amplifier calculated from the real and imaginary terms of the i_5, e_g ratio is shown here.



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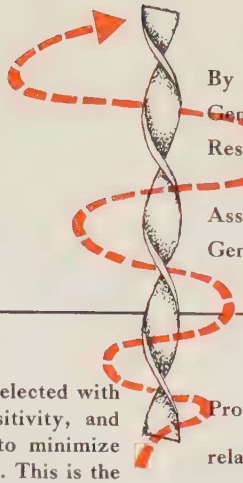
Acknowledgment

The author acknowledges the help of C. F. Springer of the Engineering Department, Delco Radio Division, who performed the computer programming work required for this study.

Solution to the Previous Problem:

Complete the Design of a Torque Measuring Instrumentation System



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Assisted by James Bay
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The design of a torque measuring system requires that each component be selected with respect to the others to meet requirements of frequency response, sensitivity, and impedance matching. Impedance relationships are particularly important to minimize electrical loading with its possible adverse effect on the unit being measured. This is the solution to the problem presented in the July-August-September 1960 issue of the GENERAL MOTORS ENGINEERING JOURNAL. The problem required the determination of certain parameters needed to design the matching network and recorder components of a system used to measure the instantaneous fluctuations of load on an automatic transmission. The design of the transducer component of the measuring system was the basis for a previously published typical problem in engineering*.

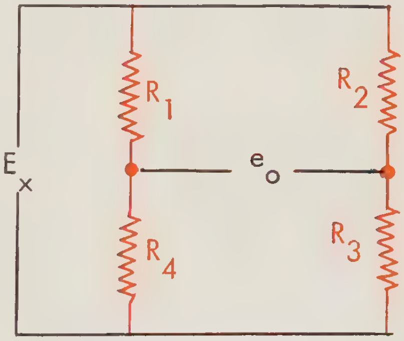
Proper impedance relationships must be provided

THE function of the matching network component of a measuring system is to transfer the signal picked up by the transducer to the recorder. The network must be designed to have a sufficiently high impedance to prevent loading of the transducer and also must provide a signal at the power level required to drive the recorder. This drive signal may require either amplification or attenuation of the transducer signal. The recorder component of the measuring system, in turn, must convert the electrical drive signal to a record of the measured phenomena with respect to time.

To establish specifications for these two components used in the system to measure the torque between an automatic transmission and a dynamometer, certain parameters had to be determined. The solution to the problem is divided into six basic parts, each of which deals with a parameter presented in the problem.

Part (a)—Maximum Bridge Excitation Voltage and Output Voltage at Maximum Torque

The strain gage, shaft-type torquemeter* used to measure the torque transmitted from an automatic transmission to a dynamometer was composed of four Type AB-1 resistance wire strain gages R_1, R_2, R_3, and R_4. These gages, having a nominal resistance R of 350 ohms, were connected to form a Wheatstone bridge circuit, as follows:

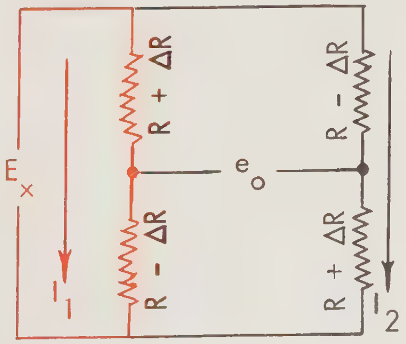


where

E_x = strain gage bridge excitation voltage

e_o = bridge output voltage.

The torquemeter, or transducer, was designed to provide an output voltage e_o of 9.1 millivolts at a maximum design torque of 11,910 in-lb with 5 volts d-c excitation.



Maximum Excitation Voltage

Referring to the circuit diagram at the bottom of the preceding column,

where

R = strain gage resistance at no load = 350 ohms

ΔR = change in gage resistance due to load

I_1, I_2 = branch currents,

the equation for excitation voltage E_x may be written as follows:

$$E_x = [(R + \Delta R) + (R - \Delta R)]\, I_1$$

$$E_x = 2R(I_1). \qquad (1)$$

It was mentioned in the statement to the problem that a good "rule of thumb" is to limit the strain gage current to 25 milliamperes. Substituting this value for I_1 in equation (1) and also the value of 350 ohms for R gives the following value for excitation voltage:

$$E_x = 2(350)(25)(10^{-3}) = 17.5 \text{ volts.}$$

By specifying the excitation voltage as 15 volts, a margin of safety is obtained and a low impedance load can be used without harmful effects to the strain gages.

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*Please see "A Typical Problem in Engineering: Determine the Basic Design Parameters for a Strain Gage, Shaft-Type Torquemeter," April-May-June 1960 issue, pp. 55-58. The solution to this problem appeared in the July-August-September 1960 issue, pp. 49-51.

Output Voltage at Maximum Torque

The general equation for the open-circuit voltage e_o can be written as follows:

$$I_1 = \frac{E_x}{(R+\Delta R)+(R-\Delta R)} = \frac{E_x}{2R}$$

$$I_2 = \frac{E_x}{2R} = I_1$$

$$e_o = I_2(R+\Delta R) - I_1(R-\Delta R)$$

$$e_o = \frac{E_x(R+\Delta R - R + \Delta R)}{2R}$$

$$e_o = \frac{E_x \Delta R}{R}. \qquad (2)$$

The output voltage at the maximum design torque of 11,910 in-lb may be calculated by substituting known values for E_x, R, and the change in gage resistance ΔR into equation (2).

$$e_o = \frac{15(0.637)}{350}$$

e_o = 27.3 millivolts at maximum torque.

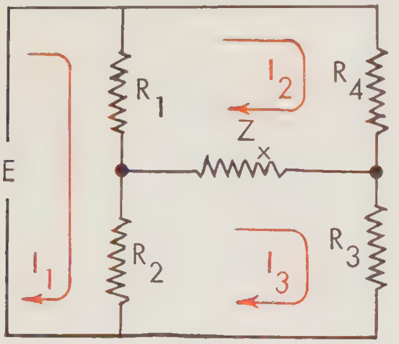
Part (b)—Effect of Excitation Voltage Drift

If $\Delta R/R$ in equation (2) is equal to a constant K, the output voltage e_o would then be equal to KE_x. If E_x is doubled, the output voltage will double in value. If E_x is decreased to half of its original value, then e_o also will be decreased by one-half.

The conclusion to be drawn from this relationship between bridge excitation voltage E_x and output voltage e_o is that the excitation voltage must be closely regulated if highly accurate measurements are to be obtained.

Part (c)—Output Impedance of Bridge

The output voltage of the strain gage bridge may be greatly affected by the relationship between the input impedance of the matching network and the output impedance of the bridge. To examine this effect, the equation for the output impedance Z_o may be derived from the following circuit diagram.



This circuit diagram is the same as that used for deriving the maximum voltage excitation except that a voltage E is applied to the output terminals and the excitation voltage E_x has been replaced by its internal impedance Z_x. The voltage E applied to the output terminals produces the loop currents I_1, I_2, and I_3. The output impedance of the strain gage bridge is equal to the ratio E/I_1.

Balanced Bridge

Loop, or mesh, equations can be written for a balanced bridge as follows.

Assume that

$$R_1 = R_2 = R_3 = R_4 = R.$$

Then,

$$E = I_1(R_1+R_2) - I_2R_1 - I_3R_2$$

$$0 = -I_1R_1 + I_2(R_1+R_4+Z_x) - I_3Z_x$$

$$0 = I_1R_2 - I_2Z_x + I_3(R_2+R_3+Z_x).$$

These equations may be written in matrix form as follows.

$$\begin{bmatrix} E \\ 0 \\ 0 \end{bmatrix} = \left[\begin{array}{c|c|c} 2R & -R & -R \\ -R & (2R+Z_x) & -Z_x \\ -R & -Z_x & 2R+Z_x \end{array}\right] \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

Solving the matrix equations gives:

$$I_1 = \frac{E}{R};\ I_2 = \frac{E}{2R};\ I_3 = \frac{E}{2R}.$$

The output impedance is equal to:

$$Z_o = \frac{E}{I_1} = R. \qquad (3)$$

Resistance R is equal to 350 ohms. Therefore,

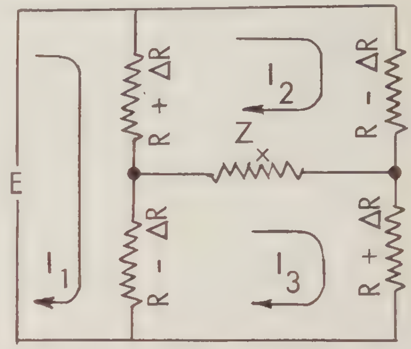
Z_o = 350 ohms.

Equation (3) states that the output impedance of the four-gage balanced bridge, with all strain gages of equal resistance, is equal to the resistance of one gage. This equation also indicates that under these conditions the internal impedance of the excitation source has no effect on the output impedance.

Unbalanced Bridge

The design of a transducer is such that an output voltage is produced only when the bridge is unbalanced by a mechanical load. The effect on output impedance, therefore, caused by unbalancing the bridge, must be examined.

In the following circuit diagram, ΔR represents the change in gage resistance due to mechanical loading.



The loop equations for this unbalanced bridge are:

$$E = I_1(2R) - I_2(R+\Delta R) - I_3(R-\Delta R)$$

$$0 = -I_1(R+\Delta R) + I_2(2R+Z_x) - I_3 - Z_x$$

$$0 = -I_1(R-\Delta R) - I_2Z_x + I_3(2R+Z_x).$$

The loop equations in matrix form are:

$$\begin{bmatrix} E \\ 0 \\ 0 \end{bmatrix} = \left[\begin{array}{c|c|c} 2R & -(R+\Delta R) & -(R-\Delta R) \\ -(R+\Delta R) & 2R+Z_x & -Z_x \\ -(R-\Delta R) & -Z_x & 2R+Z_x \end{array}\right] \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

Solving the matrix equations gives:

$$I_1 = \frac{E(R+Z_x)}{(R^2+RZ_x-\Delta R^2)}$$

$$I_2 = \frac{R(R+Z_x+\Delta R)}{2(R^2+RZ_x-\Delta R^2)}$$

$$I_3 = \frac{E(R+Z_x-\Delta R)}{2(R^2+RZ_x-\Delta R^2)}.$$

The output impedance of the bridge is:

$$Z_o = \frac{E}{I_1} = \frac{R^2+RZ_x-\Delta R^2}{R+Z_x}. \qquad (4)$$

Substituting the following typical values

R = 350 ohms
ΔR = 1 ohm
Z_x = 1 ohm

into equation (4) gives the magnitude of the change in output impedance due to the change in gage resistance.

$$Z_o = \frac{(350)^2 + 350 - 1}{350 + 1}$$

In the above equation, $\Delta R^2 = 1$ is negligible in comparison to $R^2 = 122{,}500$. Therefore,

$$Z_o = \frac{R^2 + RZ_x}{R + Z_x} = \frac{R(R + Z_x)}{R + Z_x}$$

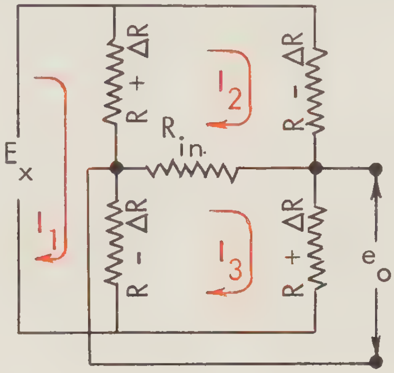
$$Z_o = R.$$

This shows that, although the bridge is unbalanced, Z_x still has no effect on the output impedance and that the small amount of unbalance has a completely negligible effect on the bridge output impedance.

It may seem that solving the equations for the unbalanced bridge is quite involved, especially when the results only indicate that the unbalance has no noticeable effect. In practice, however, it is just as important to determine what factors will have no effect as well as to determine what factors will influence the results desired.

Part (d)—Effect of Electrical Loading on Bridge Output Voltage

The output voltage of the bridge may be greatly affected by the input impedance of the matching network. In the following circuit diagram, the input impedance is represented by R_{in}.



Loop equations may be written as follows for currents I_1, I_2, and I_3.

$$I_1 = \frac{E_x(R + R_{in})}{R^2 + R(R_{in}) - \Delta R^2}$$

$$I_2 = \frac{E_x(R + \Delta R + R_{in})}{2[R^2 + R(R_{in}) - \Delta R^2]}$$

$$I_3 = \frac{E_x(R - \Delta R + R_{in})}{2[R^2 + R(R_{in}) - \Delta R^2]}$$

$$e_o = (I_2 - I_3)R_{in}$$

$$e_o = \frac{E_x(R_{in})(\Delta R)}{R^2 + R(R_{in}) - \Delta R^2}. \qquad (5)$$

If R_{in} equals infinity, then

$$e_o = \frac{E_x \Delta R}{R}.$$

This is the maximum signal value that can be obtained for a given ΔR. Using this as a 100 per cent reference value, other values of R_{in} with respect to R can be substituted into equation (5) to determine the effect of electrical loading on the output voltage. The results can be plotted on semi-log paper (Fig. 1). To avoid any appreciable amount of attenuation of the output signal voltage, R_{in} should be at least 10 times R, the output impedance of the bridge. Direct-current amplifiers are available with input impedances in the range of ten thousand to one million ohms for use with bridges using resistance wire strain gages.

Another effect of electrical loading is to draw more current through the gages when the bridge is unbalanced. Excessive current will cause local heating in a gage and produce undesirable temperature effects and erroneous results. With a ratio of R_{in} to R of 10 or greater, excessive current due to loading usually is negligible.

If the output voltage signal for the maximum transducer operating range is sufficiently small, excessive current loading will not occur, even for very low values of load resistance. Loading conditions, therefore, require attention to output signal swing as well as impedance matching or mismatching.

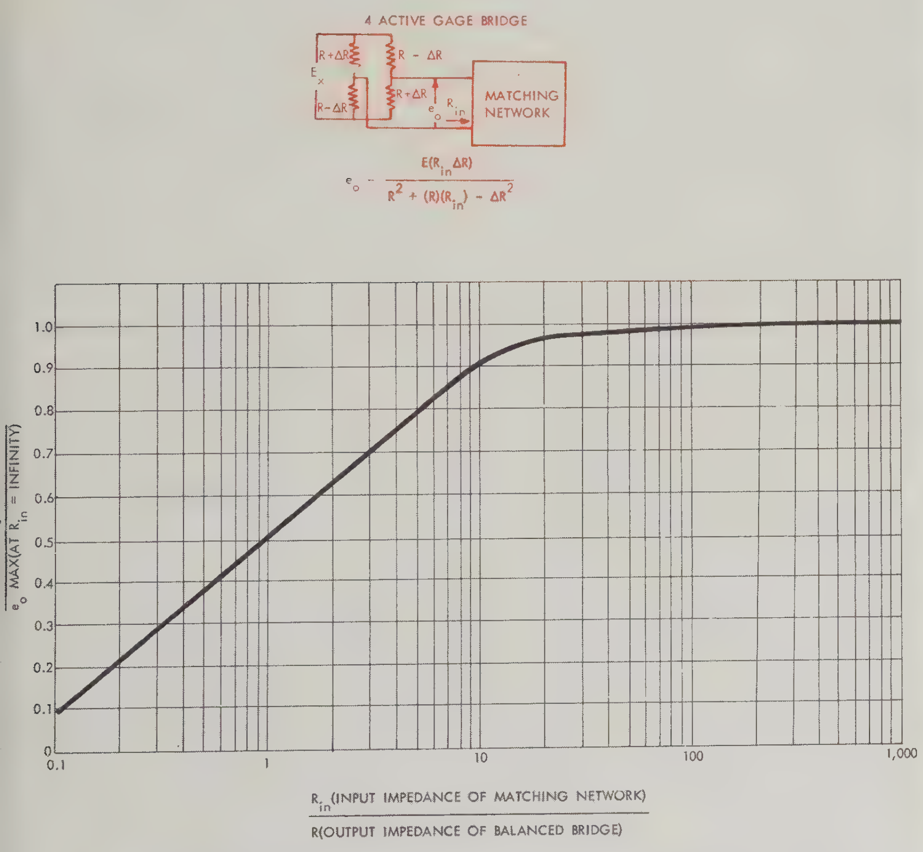


Fig. 1—This plot shows the effect of electrical loading on the output voltage of a bridge composed of four active resistance wire strain gages.

Part (e)—Frequency Response and Galvanometer Selection.

A light beam oscillograph was used to record the signal provided by the torque transducer. This type of recorder was selected because of its ability to simultaneously record many channels of information for visual presentation and because it has relatively high frequency capabilities.

Once a recorder has been selected, the next step is to select a galvanometer. Before a galvanometer can be selected, however, the highest frequency component of the torque transients must be determined.

Frequency Response

Since the exact nature of the torque transients usually is not accurately known, some reasonable, although arbitrary, assumptions must be made. The method used for this particular problem to determine the highest frequency response to be recorded is based on the maximum rise-time of the dynamometer speed signal.

The rise-time is measured from a preliminary recording of the transmission output speed (Fig. 2). This test record shows the point of greatest slope of the speed versus time curve during which the highest frequency component of the speed signal is present. The problem stated that the maximum frequency capability of the galvanometer must be at least 10 times the high-frequency component of the speed signal.

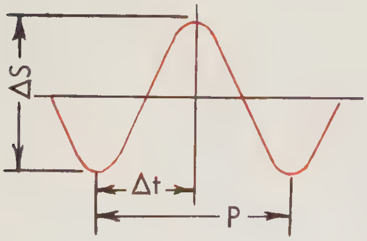
The test record shows a maximum slope on the first portion of the dynamometer speed curve (Point 10, Curve No. 3, Fig. 2), which also is the same as transmission output speed. The maximum frequency can be determined from this slope as follows.

In the following figure, assume that

Δt = one-half of the period of a sine wave whose frequency f is $\frac{1}{P}$

Δs = peak-to-peak amplitude

P = period of one cycle.



The equations for the frequency-time relationship are:

$$\Delta t = \frac{P}{2}$$

$$f = \frac{1}{P} = \frac{1}{2\Delta t}.$$

The value of Δt can be measured from the test record (Fig. 2) as approximately 0.32 seconds. Therefore,

$$f = \frac{1}{2(0.32)} = 1.56 \text{ cycles per sec.}$$

The maximum frequency response required to record the torque transients, therefore, is $10f$ or 15.6 cycles per sec.

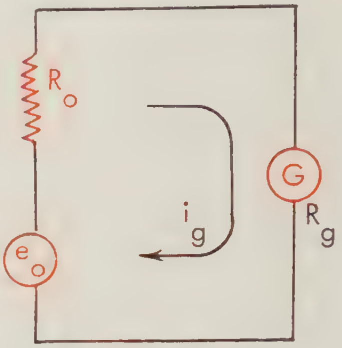
Galvanometer Selection

The galvanometer required for the measuring system now can be determined based on maximum frequency response. The characteristics of several galvanometers are presented in Table I. From the galvanometers listed, galvanometer No. 1 is best suited to meet the required frequency response. The characteristics of this galvanometer are:

- Frequency range = 0 to 30 cycles per sec
- Sensitivity = 0.217 in. per microampere
- Coil resistance = 30 ohms
- Required external damping resistance = 350 ohms.

Part (f)—Galvanometer Damping and Signal Attenuation of the Matching Network

With a bridge excitation voltage of 15 v, the maximum output voltage is 27.3 millivolts for the open circuit condition. If the galvanometer were connected directly across the bridge output, the output voltage would be reduced to approximately 2.7 millivolts. The galvanometer, however, is a low impedance, current-sensitive device. The load current flowing at the low signal voltage, which results when the galvanometer is directly connected across the output of the bridge, can be determined from the following circuit diagram.



In this circuit, R_o and e_o are the Thevenin equivalent circuit of the strain gage bridge and G is the galvanometer. The open circuit output impedance is R_o and e_o is the open circuit output voltage. The load current i_g, therefore, is equal to:

$$i_g = \frac{e_o}{R_o + R_g}$$

e_o = 27.3 millivolts

R_o = 350 ohms

R_g = 30 ohms.

Therefore,

$$i_g = \frac{27.3(10^{-3})}{380}$$

$$i_g = 0.0718\ (10^{-3}) \text{ amperes.}$$

Or,

$$i_g = 71.8 \text{ microamperes.}$$

This is the maximum galvanometer current that can be directly obtained from the strain gage bridge. Four inches of galvanometer deflection was specified at maximum torque. The sensitivity of the galvanometer selected in Part (e) is 0.217 in. per microampere. For four

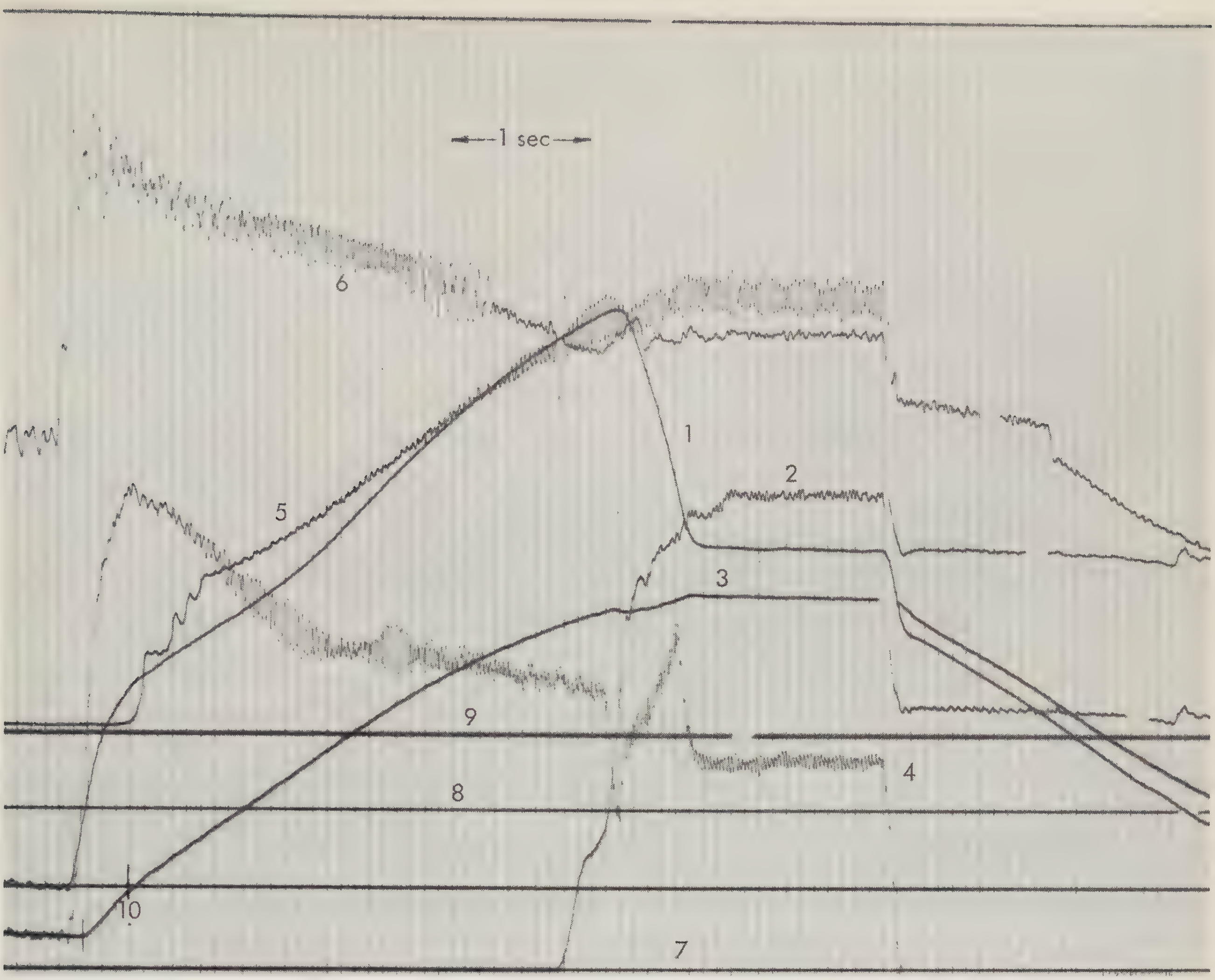


Fig. 2—This is a typical light beam oscillograph record made by the Fuels and Lubricants Department of the General Motors Research Laboratories during an automobile transmission test. The traces shown on the record are as follows: engine speed *1*, clutch pressure *2*, dynamometer speed *3*, output torque *4*, governor pressure *5*, and main line pressure *6*. The paper speed for this particular record was 0.9 in. per sec. This provided a time base of 1.111 sec per in. Each timing mark (vertical lines) represents a timing interval of 0.1 sec. The test was calibrated for an engine speed of 1,000 rpm per in., a clutch pressure of 30 psi per in., a dynamometer speed of 1,000 rpm per in., an output torque of 200 lb per in., a governor pressure of 30 psi per in., and a main line pressure of 30 psi per in. Line *7* is the zero reference line for engine speed, clutch pressure, dynamometer speed, and output torque. Line *8* is the zero reference line for main line pressure and line *9* is the zero reference line for governor pressure. Point *10* indicates the portion of the dynamometer speed curve used to determine the maximum frequency response required of the torque measuring system.

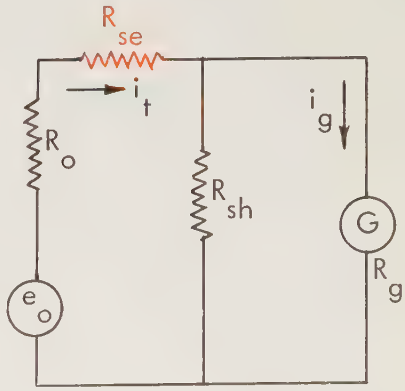
inches of deflection, the required galvanometer current i_g is 4/0.217, or 18.4 microamperes. Direct connection of the galvanometer to the output of the bridge, therefore, is unsatisfactory because the galvanometer current is too large.

It should be noted that, although the current causes a greater galvanometer deflection than is desired, it still is quite small because of the small signal voltage. The current, in addition to the no-load current through the strain gage, is not enough to cause excessive electrical loading.

The desired current could be obtained by decreasing the bridge excitation voltage. The signal-to-noise ratio, however, also would be reduced. The 350 ohm output impedance of the transducer is conveniently equal to the required damping resistance of the galvanometer. The conditions for direct connection of the galvanometer to the bridge, therefore, are ideal except that the signal-to-noise ratio must be kept as high as possible because of slip ring noise.

To keep a high signal-to-noise ratio through the slip rings, the signal must be attenuated in the galvanometer circuit rather than in the bridge circuit. A series resistor will limit the current to provide the required deflection, but the required 350 ohm damping resistance also must be provided.

The following circuit is the one required to provide both attenuating and the proper damping resistance.



In this circuit,

e_o = bridge output voltage with no load

R_o = bridge output impedance

R_{se} = series resistance

R_{sh} = shunt resistance

R_D = required damping resistance

i_g = galvanometer current

i_t = total load current

R_g = galvanometer resistance.

From the circuit diagram,

$$i_t = \frac{e_o}{R_o + R_{se} + \dfrac{R_gR_{sh}}{R_g + R_{sh}}}$$

$$i_g = \frac{(i_t)(R_{sh})}{R_{sh} + R_g}.$$

Therefore,

$$i_g = \frac{e_oR_{sh}}{\left(R_o+R_{se}+\dfrac{R_gR_{sh}}{R_g+R_{sh}}\right)(R_g+R_{sh})}. \qquad (6)$$

Substituting the following values

e_o = 27.3 millivolts

i_g = 18.4 microamperes

R_o = 350 ohms

R_D = 350 ohms

R_g = 30 ohms

into equation (6) and reducing gives:

$$20.3(10^{-3})R_{sh} - 0.552(10^{-3})R_{se} - 18.4(10^{-6})R_{se}R_{sh} = 0.1931. \qquad (7)$$

The relationship between R_{se} and R_{sh} to provide proper damping is given by the following equation:

$$R_D = \frac{R_{sh}(R_o + R_{se})}{R_{sh} + R_o + R_{se}}. \qquad (8)$$

Substituting known values into equation (8) gives

$$R_{se}R_{sh} - 350R_{se} = 122.5(10^{-3}). \qquad (9)$$

Simultaneous solution of equations (7) and (9) gives

R_{sh} = 470.52 ohms

R_{se} = 1,017 ohms.

The final circuit for the measuring system is shown in Fig. 3.

Measuring System Redesigned to Give Higher Frequency Response

Since the required frequency response was arbitrarily determined, it is possible that the first test records obtained will show that higher frequency response is needed.

It was stated in the problem to assume that the frequency response must be increased by a factor of ten. The following analysis will show the circuit changes required to accomplish this increase in frequency response. The same transducer and torque range will be used. The bridge excitation voltage will remain at 15v, which will provide the same 27.3 millivolt open circuit voltage.

Increasing the frequency response by a factor of ten will change the required upper frequency from 15.6 cps to 156 cps. This change requires a different galvanometer in order to extend the upper frequency limit. Referring to Table I, galvanometer No. 2 will provide the required frequency response. The desired galvanometer deflection at maximum torque was to remain at four inches. The required galvanometer current i_g, therefore, may be determined as follows:

$$i_g = \frac{\text{required deflection}}{\text{galvanometer sensitivity}}$$

$$i_g = \frac{4}{0.0037} = 1.081 \text{ milliamperes.}$$

Direct connection of the galvanometer to the bridge output will provide the following galvanometer current.

$$i_g = \frac{e_o}{R_o + R_g}$$

$$i_g = \frac{27.3(10^{-3})}{350 + 40}$$

$$i_g = 70 \text{ microamperes.}$$

The calculated value of i_g is much smaller than 1.081 milliamperes required for four inches of galvanometer deflection. Some amplification, therefore, will be required between the transducer and the galvanometer.

The problem stated the characteristics of the d-c amplifier to use if amplification is required. Referring to Fig. 1, it can be seen that with a 100,000-ohm load on the bridge, the output voltage will be

GALVANOMETER CHARACTERISTICS

GALVANOMETER NUMBER	FREQUENCY RANGE (CPS)	SENSITIVITY (IN. PER MICROAMPERE)	COIL RESISTANCE (OHMS)	EXTERNAL DAMPING RESISTANCE (OHMS)
1	0-30	0.217	30	350
2	0-180	0.0037	40	83
3	0-350	0.0022	22	25
4	0-600	0.0004	24	1,000
5	0-1,200	0.000109	24	200
6	0-3,000	0.000031	52	55

Table I—This is a listing of various characteristics of six galvanometers from which one was to be selected to meet the required frequency response of the torque measuring system. In general, as the frequency response range increases, the sensitivity decreases.

attenuated very little. The actual value may be found as follows:

$$R_{in} = 100{,}000 \text{ ohms}$$

$$R = 350 \text{ ohms}$$

$$\frac{R_{in}}{R} = \frac{100{,}000}{350} = 285.7.$$

From Fig. 1:

$$\text{When } \frac{R_{in}}{R} = 285.7,$$

$$\frac{e_o}{e_o \text{ (max)}} = 0.993$$

$$e_o \text{ (max)} = 27.3 \text{ millivolts.}$$

The actual output voltage e_o, therefore, is

$$e_o = (0.993)(27.3)(10^{-3})$$

$$e_o = 27.1 \text{ millivolts.}$$

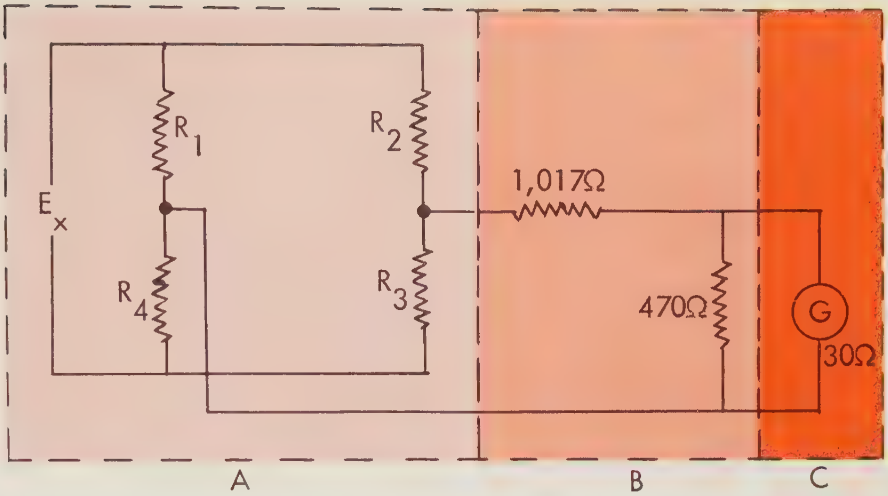
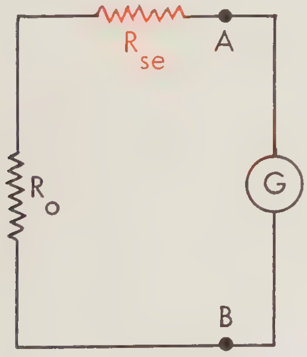


Fig. 3—This is the circuit used to measure and record the signal picked up by the strain gage torque transducer. Section *A* is the transducer comprised of four resistance wire strain gages R_1, R_2, R_3, and R_4. Strain gage bridge excitation voltage is denoted by E_x. Section *B* is the matching network of the system, comprised of a 1,017 ohm resistor and a 470 ohm resistor. Section *C* is the active element of the recorder, which is the galvanometer *G*.

The external damping resistance required for galvanometer No. 2 is 83 ohms. The output impedance of the d-c amplifier was given as less than one ohm. The damping resistance required can be obtained by adding a series resistance R_{se} between the d-c amplifier and the galvanometer, as indicated in the following circuit diagram,



where

R_D = circuit resistance from A to B with the galvanometer removed

R_D = required damping resistance

$R_D = R_o + R_{se}$

R_o = d-c amplifier output impedance

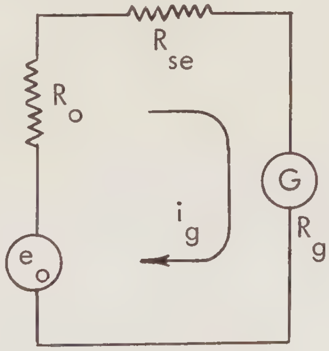
R_{se} = series resistance to be added.

Using one ohm as the output impedance, the series resistance R_{se} to be added can be calculated as follows:

$$R_{se} = R_D - R_o$$

$$R_{se} = 83 - 1 = 82 \text{ ohms.}$$

The d-c amplifier output voltage e_o required to produce four inches of galvanometer deflection may be determined by referring to the following circuit diagram.



$$e_o = i_g\,(R_o + R_{se} + R_g)$$

$$e_o = 1.081(10^{-3})(123)$$

$$e_o = 133 \text{ millivolts.}$$

The required voltage amplification A can now be calculated as follows:

$$A = \frac{e_o}{e_{in}}$$

where

e_o = d-c amplifier output voltage

e_{in} = d-c amplifier input voltage (This is also the bridge output voltage with a 100,000-ohm load).

$$A = \frac{133(10^{-3})}{27.1(10^{-3})} = 4.905.$$

The lowest amplification obtainable from the d-c amplifier is 20. This is the value which must be set on the d-c amplifier. Some voltage attenuating adjustment, however, must be provided at either the d-c amplifier input or in the galvanometer circuit. Because any resistance adjustment in the galvanometer circuit will affect the damping, the attenuating adjustment may be most easily provided by using a shunt potentiometer across the d-c amplifier input terminals.

The completed measuring circuit used to provide increased frequency response is shown in Fig. 4. The matching network for this circuit is composed of a d-c amplifier, a potentiometer R_a, and a series resistor R_{se}.

The value of R_a should be kept high with respect to the bridge output impedance to avoid unnecessary voltage attenuation due to loading. Also, the value of R_a should be low with respect to the

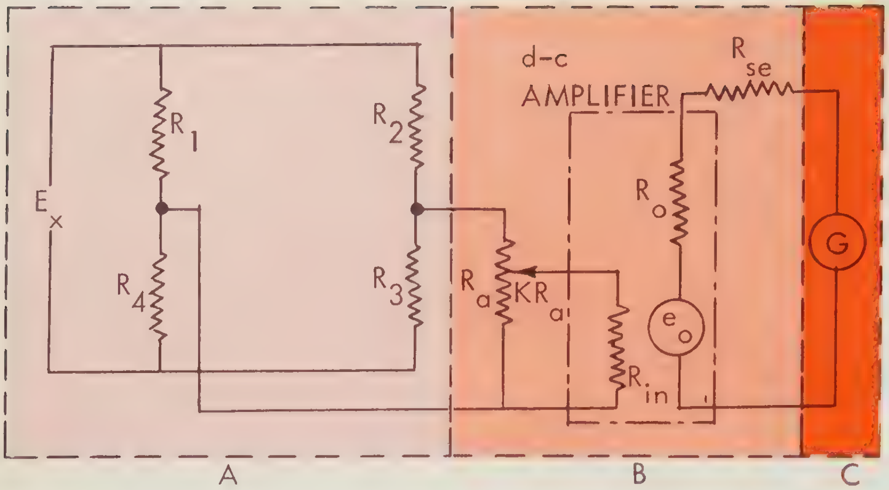


Fig. 4—This is the circuit used to provide for increased frequency response for the torque measuring system. Section *A* is the transducer, section *B* is the matching network, and section *C* is the recorder whose active element is the galvanometer *G*. The matching network is comprised of a potentiometer R_a, a d-c amplifier, and a series resister R_{se}.

input impedance of the d-c amplifier to minimize the change in loading when R_a is adjusted. A good value for R_a, therefore, would be in the range of from 5,000 to 10,000 ohms.

If 10,000 ohms is used as the load on the bridge, the ratio of this load to bridge output impedance will be 10,000/350, or 28.57. Referring to Fig. 1:

$$\text{When } \frac{R}{R_o} = 28.57,$$

$$\frac{e_o}{e_{o\,(max)}} \cong 0.968.$$

Therefore,

$$e_o = (0.968)(27.3) = 26.42 \text{ millivolts.}$$

For 133 millivolts out of the d-c amplifier at a gain of 20, the voltage e_{in} into the amplifier must be 133/20, or 6.65 millivolts.

The potentiometer R_a must attenuate the 26.42 millivolts to provide 6.65 millivolts at the amplifier input. If R_a is used as a voltage divider, the following relationship determines the value of *K*, or the position of the potentiometer arm, for the desired output.

$$\frac{e_o}{R_a} = \frac{e_{in}}{KR_a} \qquad (10)$$

where

e_o = bridge output voltage with 10,000-ohm load
e_{in} = required input voltage to d-c amplifier
R_a = potentiometer
KR_a = the portion of the potentiometer connected across the amplifier input to give the required input voltage.

Substituting known values into equation (10) and solving for *K* gives:

$$\frac{26.42(10^{-3})}{10{,}000} = \frac{6.65(10^{-3})}{K(10{,}000)}$$

$$K = 0.2516$$

The potentiometer R_a can be continuously adjusted to provide any input voltage between zero and 26.42 millivolts to the d-c amplifier. Rather than calculate the value for *K*, as was just done, the usual procedure is to adjust *K* for the desired galvanometer deflection during calibration of the measuring system.

Calibration

Once the measuring system is designed, it must then be calibrated. The output must be set or adjusted to a desired value for a known input. To calibrate the measuring system to meet the conditions of this problem, an accurately known value of torque would be applied to the transducer. The potentiometer R_a would then be adjusted to set the desired deflection of the galvanometer.

If reasonable care is taken in selecting the components of the measuring system, the accuracy of the measurements will then depend on the care exercised during calibration. Also during the calibration procedure, the effects of temperature change, amplifier drift, and other possible variables in the system must be ascertained. These effects become increasingly important as the required accuracy for a particular measurement is increased.

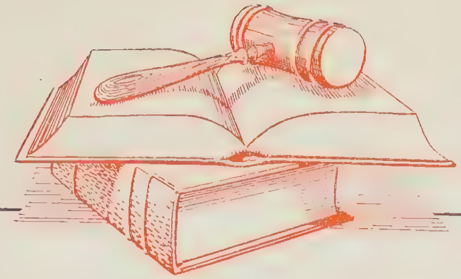
Summary

The solution to this problem has been based on determining the maximum frequency response required. This has applied to the first part of the solution, when the required frequency response was relatively low, as well as for the last part of the solution where the frequency response requirement was increased by a factor of ten.

The difference in frequency response requirements illustrates several important points. When frequency requirements are relatively low, the inherent high sensitivity of the galvanometer may eliminate the need for any active element between the transducer and the recorder. A frequency response of relatively high value can be obtained, but nearly always at the cost of reduced galvanometer sensitivity. The reduction in sensitivity usually requires some amplification between the transducer and the recorder. As shown by the solution, galvanometer damping may be accomplished in various ways. The method usually used is dependent on other factors such as the overall system sensitivity, output impedance of the matching network, or the output impedance of the transducer.

The procedure used in solving this problem is similar to that used by the GM Research Laboratories for instrumentation system design work. The components specified for this particular problem are typical of commercial instruments available. As experience is gained in instrumentation work, some of the calculations can be shortened or eliminated, as long as they have been considered and the required relationships are correct. It is particularly important to provide the proper impedance relationships throughout the measuring system. This almost always requires a large mismatch of impedances to prevent loading rather than matching for maximum power transfer.

Court Made Law



By ROBERT B. GERHARDT
Patent Section
Detroit Office

When one speaks of the law on a particular subject it is important to know what is meant by the word *law*. In the case of Patent Law, like most other fields of law, the *law* is composed not only of statutes or a code passed by the legislature, but also includes the conclusions set forth in a multitude of court decisions in which the rights of inventors under these statutes are determined. Thus the whole *law* consists not only of the written statutes but also of numerous court decisions interpreting these statutes. Sometimes the law seems either to contain conflicting rules or is so ambiguous that it is difficult or impossible to predetermine the outcome of a legal controversy. Often the lower courts are overruled by higher courts and sometimes the higher courts reverse themselves.

It is impractical to provide specific provisions in the statutes for every situation which has arisen in the past. Also, it is impossible to anticipate all the problems or situations that may arise in the future. Thus it is necessary to litigate controversies arising out of these situations before the courts. The court decisions resulting from this litigation become part of the law and are as binding as statute law and are usually given full effect by other courts. In some instances the legislature codifies this judge or court made law. Sometimes if there are court decisions which are contrary to the wishes of the legislature, the legislature will specifically overrule the court made law by enacting specific changes or additions in the statutes.

Because of this dual makeup of the law, it is not possible merely to refer to applicable statutes in determining what one's specific or general rights are in a given factual situation. This is true in the case of patent law as well as in other fields of law.

For example, originally the patent statute's requirements as to who could obtain a patent were and still are quite general. Gradually over the years, while ruling on specific patent cases, the courts rendered decisions that set forth the proposition that one must be the *first* and *original* inventor in order to obtain a valid patent. The terms *first* and *original* were not and still are not used in the statutes except as to the oath the inventor must make stating what he believes are the facts when applying for a patent. The term *original* as used here simply means that the applicant inventor himself invented the subject matter. Therefore, there can be more than one original inventor of a given invention since several inventors may independently conceive of the same thing. Since 1953 the patent statutes specifically provide that a person is not entitled to a patent if "he did not himself invent the subject matter sought to be patented."

The meaning of the term *first* requires more analysis, since to be able to determine who is first, it is necessary to initially decide what it is that one must first do. In other words, when is an invention made? The statutes as passed by Congress gave no direct answer on this point so the courts have over the years firmly established that generally an invention is not complete until it is reduced to practice by reducing the idea to a practical, physical form. Thus the original idea, known as the conception, does not by itself, form an invention. There must be a making and testing of a physical embodiment such that it is certain that the invention will do what it is intended to do and so that others skilled in the art can practice the invention. This step of making and testing is known as *reducing the invention to practice.*

In determining who is the first inventor both the date of conception and reduction to practice are important. The courts have made a further rule that is now universally accepted. If inventor *A*, who is the first one to conceive, uses reasonable diligence in adapting or perfecting his invention, then even though another inventor *B* has independently and hence originally reduced the invention to practice before the completion or perfection by *A*, the first inventor is *A* and only he is entitled to a patent.

Dual makeup of the *law;* written statutes, court interpretations

Another concept in patent law, not set forth in the written statutes, but which is now a fully accepted legal rule, is known as *constructive reduction to practice.* This rule or doctrine also has arisen solely by court decisions. Under this rule actual physical reduction to practice is not always required to complete the invention. An exception exists when the inventor has done all that he is required to do to obtain a valid United States patent, namely, filed a complete patent application which contains a full disclosure sufficient to enable one skilled in the art to make and use the invention. In such a case the filing of the application is considered the equivalent of an actual reduction to practice and the inventor need do nothing further to complete the invention. The reasoning behind this can be seen from the words of the U. S. Supreme Court in ruling on one of Alexander Graham Bell's telephone patents (No. 174,465) in 1888. In this ruling the court said:

> "It is quite true that when Bell applied for his patent he had never actually transmitted telegraphically spoken words so that they could be distinctly heard and understood at the receiving end of his line, but in his specification he did describe accurately and with admirable clearness his process, that is to say, the exact electrical condition that must be created to accomplish his purpose; and he also described, with sufficient precision to enable one of ordinary skill in such matters to make it, a form of apparatus which, if used in the way pointed out, would produce the required effect, receive the words, and carry them to and deliver them at the appointed place. The particular instrument which he had and which he used in his experiments did not, under the cir-

cumstances in which it was tried, reproduce the words spoken, so that they could be clearly understood, but the proof is abundant and of the most convincing character, that other instruments, carefully constructed and made exactly in accordance with the specification, without any additions whatever, have operated and will operate successfully.

"The law does not require that a discoverer or inventor, in order to get a patent for a process, must have succeeded in bringing his art to the highest degree of perfection. It is enough if he describes his method with sufficient clearness and precision to enable those skilled in the matter to understand what the process is, and if he points out some practicable way of putting it into operation. This Bell did."

What the Supreme Court meant by the statement that "The law does not require . . .", is that they interpret the statute to mean that it is not required.

It should be noted that the rules stated above relating to the first inventor are only general rules and that there are many special situations which must be considered. The law in these special situations is determined by the court's interpretation of the statutes.

Thus it can be seen that each particular legal question and controversy that arises in a patent case requires an independent analysis not only of the specific applicable statutes but also a review of the multitude of court decisions which have gradually expanded, limited, and interpreted the statutes and their meaning. It is these decisions that really state what the law is.

Notes About Inventions and Inventors

Contributed by
Patent Section
Detroit Office

The following is a general listing of patents granted in the names of General Motors employes during the period April 1, through June 30, 1960.

AC Spark Plug Division
Flint, Michigan

- **Henry H. Harada**, senior designer, inventor in patent 2,933,568 for an electric switch.

- **James A. Norton**, (*associate in science degree, Flint Junior College, 1934; S. B. Degree, 1936; and Ph.D. degree in organic chemistry, 1939; University of Chicago*) research scientist, inventor in patent 2,933,604 for a method for testing oil filter elements.

- **Edwin F. Katz**, (*M.S.M.E., The Ohio State University, 1950, and B.S.M.E., University of Wisconsin, 1941*) assistant head, Development Section, Milwaukee plant, inventor in patent 2,934,961 for a gyroscope compensation torque device.

- **Joseph Zubaty**, (*M.S.M.E., University of Prague, 1918*) staff engineer, inventor in patent 2,935,063 for a variable pressure fluid drive mechanism.

- **Joseph N. Heller**, (*B.S.M.E., and B.S.E.E., Clemson College, 1928*) assistant staff engineer, inventor in patent 2,936,853 for an air cleaner means.

- **Homer R. Hastings**, (*B.S.E.E., Michigan State University, 1939*) staff engineer, and Clarence Haut, no longer with GM, inventors in patent 2,939,078 for an electrical measuring instrument.

- **Gordon B. Elder**, (*B.S.Aero.E., University of Michigan, 1937*) staff engineer, and **Gordon W. Harry**, (*B.S.M.E., University of Michigan, 1923*) staff engineer, inventors in patent 2,939,480 for a fuel pressure regulator.

- **Earl W. Pierce**, (*B.S.M.E., University of Michigan, 1939*) senior project engineer, and **Harley E. Fortier**, (*B.S.Aero.E., Tri-State College, 1950*) aviation sales engineer, inventors in patent 2,939,983 for an igniter plug.

- **Ronald J. Sargent**, (*B.M.E., General Motors Institute, 1956*) sales correspondent, inventor in patent 2,941,548 for a selector control.

- **William F. Thornburgh**, (*B.S.M.E., Michigan State University, 1951*) project engineer, inventor in patent 2,941,620 for a filter element.

- **Robert L. Carter**, (*B.S.E.E., University of Michigan, 1951*) project engineer, inventor in patent 2,942,550 for a diaphragm pump with pulsator by-pass valve.

- **Walter A. Zale**, (*B.S. Industrial Management, Carnegie Institute of Technology, 1951*) senior process engineer, inventor in patent 2,942,891 for a work holder chuck device.

- **Michael Skunda**, research associate, production engineering, inventor in patent 2,943,139 for a cable connector.

- **Walter F. Eitel**, (*Tuebingen College, Germany*) director, advanced manufacturing research and development, inventor in patent 2,943,221 for spark plug seals.

- **Bertil H. Clason**, (*Coethen Polyteknikum, Germany, and Tekniska Skolan, Sweden*) senior project engineer, inventor in patent 2,943,302 for a telemetric system for gauges and the like.

Brown-Lipe-Chapin Division
Syracuse, New York

- **Edwin J. Pietrowicz**, (*B.M.E., General Motors Institute, 1951*) senior production engineer, and Earl C. Williams, not with GM, inventors in patent 2,917,875 for a clutching control means.

Buick Motor Division
Flint, Michigan

- **George L. Fetzer**, (*B.S.M.E., Michigan State University, 1951*) senior project engineer, and **Leonard M. Morrish**, (*Michigan State University*) staff engineer, inventors in patent 2,930,440 for an exhaust system.

- **Henry W. Boylan**, (*Wayne State University, 1929*) staff engineer, and **Harry C. Doane**, now assistant to the vice president in charge of GM Engineering Staff, inventors in patent 2,933,942 for a unitary mechanism for sequential control.

- **Joseph W. Quinlan**, (*B.S.E.E., Michigan State University, 1949*) section engineer, inventor in patent 2,934,054 for an engine starting control system.

- **William C. Kessaer**, (*Elmhurst College, Michigan State University*) reliability engineer, inventor in patent 2,939,007 for a spectrometer specimen holder.

- **Eric R. Dietrich**, senior project engineer, inventor in patent 2,939,326 for a leveling control valve mechanism.

- **Joseph D. Turlay**, (*B.S.M.E., Oregon State College, 1928*) director, Power Plant Activities, inventor in patent 2,942,594 for a combustion chamber.

Cadillac Motor Car Division
Detroit, Michigan

- **Bruce M. Edsall**, (*B.S.M.E., Wayne State University, 1942*) staff engineer, and **John B. Richardson**, (*General Motors Institute, 1948*) senior experimental engineer, inventors in patent 2,932,940 for controls for torque converter movable blades.

- **Daniel M. Adams**, (*Detroit Institute of Technology and University of Michigan*) staff engineer; **Louis P. Garvey**, (*B.M.E., University of Detroit, 1940*) assistant engineer in charge, Product Engineering Activity, Design and Drafting Department, Fisher Body Division; and **Charles J. Griswold, Jr.**, (*B.S. in engineering mechanics, Purdue University, 1953*) assistant engineer in charge, Body Engineering, Design and Drafting Department, Fisher Body Division, inventors in patent 2,936,843 for an automobile door latching system.

Chevrolet Motor Division
Detroit, Michigan

- **Frank J. Winchell**, (*Purdue University*) assistant chief engineer in charge, research and development, inventor in patent 2,932,989 for a transmission.

- **George H. Primeau**, (*Northern State Teachers College*) design engineer, inventor in patent 2,933,354 for a drive shaft bearing support.

- **William S. Wolfram**, (*B.S.M.E., University of Michigan, 1933*) assistant staff engineer, inventor in patent 2,934,335 for an oil-air pneumatic spring shock absorber.

- **Kurt Hoeffgen**, (*General Motors Institute*) supervisor, Die Design Department, Chevrolet-Flint assembly plant; **John Mynar, Jr.**, (*B.I.E., General Motors Institute, 1950*) supervisor, machine tool and die design, Chevrolet-Flint assembly plant; and **Ronald O. Warner**, (*B.S.M.E. University of Michigan, 1929*) operations manager, Pressed Metal division, Chevrolet-Flint assembly plant, inventors in patent 2,935,273 for a dispensing head for spacer material.

- **Harry E. Barr**, (*B.M.E., University of Detroit, 1929*) chief engineer; **Eugene B. Etchells**, (*B.S.E.E., University of Michigan, 1932*) assistant staff engineer; and **Adelbert E. Kolbe**, (*University of Michigan*) assistant staff engineer, inventors in patent 2,936,857 for an engine lubricating system.

- **Loren R. Papenguth**, (*B.S.M.E., University of Michigan, 1948*) now with Rochester Products Division, inventor in patent 2,938,508 for a horizontally operable hydraulic valve lifter.

- **Joseph B. Depman**, (*B.S.M.E., Villanova University, 1950*) resident product engineer, Chevrolet Detroit Gear and Axle manufacturing plant, inventor in patent 2,938,542 for an air suspension control apparatus.

- **James O. Brafford**, (*The Ohio State University*) Chevrolet engine development group, GM Proving Ground, inventor in patent 2,938,601 for an engine oil pan.

- **David Rutherford**, superintendent, materials and production control, Chevrolet-Flint manufacturing plant, inventor in patent 2,938,637 for a spacer clip.

- **Adelbert E. Kolbe***, inventor in patent 2,939,547 for an oil pump casing and mounting for internal combustion engine.

- **Charles W. Jackman**, (*International, School of Correspondence*) assistant staff engineer, inventor in patent 2,939,718 for a tandem axle suspension with extended effective spring base.

- **Robert W. Graham**, (*B.S.M.E., University of Michigan, 1949*) senior project engineer, inventor in patent 2,939,725 for a flow ratio blocker valve for air suspension.

- **Joseph F. Bertsch**, (*B.S.M.E., University of Cincinnati, 1948*) design engineer, inventor in patent 2,930,628 for a dual height leveling device.

- **Phillip C. Bowser**, (*B.M.E., The Ohio State University*) now director, Research and Development, Buick Motor Division, and **Robert Schilling**, (*M.E. degree, Technical University, Munich, Germany, 1922*) now special assistant to the chief engineer, Adam Opel, GM Overseas Operations, inventors in patent 2,922,637 for air spring bellows.

Delco Appliance Division
Rochester, New York

- **Eugene R. Ziegler**, (*University of Rochester*) special development engineer, inventor in patent 2,936,476 for a windshield cleaning system.

- **Francis M. Ryck**, (*B.S., University of Rochester, 1950*) assistant supervisor, windshield wiper applications, inventor in patent 2,939,165 for a wiper blade.

Delco Moraine Division
Dayton, Ohio

- **Anton F. Erickson**, (*Pennsylvania State College, 1931*) senior design engineer, inventor in patent 2,940,548 for a disc brake.

***Inventors' names marked with an asterisk have biographical listings noted previously in this issue's Notes About Inventions and Inventors.**

Delco Products Division
Dayton, Ohio

- **George W. Jackson,** (*B.S.M.E., Purdue University, 1937*) assistant chief engineer, inventor in patent 2,933,104 for a control mechanism.

- **George W. Jackson*; Frank E. LaFlame,** (*Michigan State University*) senior project engineer; and **John F. Pribonic,** (*B.S.M.E., Princeton University, 1947*) staff engineer, inventors in patents 2,935,023 and 2,937,715 for a steering and air compressor lubrication system and a lubrication system for gas compressor, respectively.

Delco Radio Division
Kokomo, Indiana

- **James H. Guyton,** (*B.S.E.E., 1934, and M.S.E.E., 1935, Washington University*) chief engineer—radio, inventor in patent 2,939,053 for a radiant energy relay means.

- **Gerald M. Ford,** (*B.S.E.E., University of Toledo, 1950*) resident applications engineer, west coast office, inventor in patent 2,941,119 for a transistorized ignition system.

Delco-Remy Division
Anderson, Indiana

- **Lyman A. Rice,** (*B.S.E.E., University of Utah, 1935, and M.S.E.E., University of Michigan, 1936*) staff engineer, inventor in patents 2,932,774 and 2,943,169 for an electric circuit arrangement and a regulator, respectively.

- **Ward Cole,** general foreman, Engineering Model Shop, inventor in patent 2,937,409 for a method of manufacture.

- **Arthur W. Alexander,** (*B.S.E.E., University of Illinois, 1951*) sales engineer, and Paul L. Schneider, deceased, inventors in patent 2,939,964 for a starting system.

These patent listings are informative only and are not intended to define the coverage which is determined by the claims of each one.

- **John M. Doyle,** (*B.S.M.E., Purdue University, 1929*) staff engineer, and **Garth A. Rowls,** (*B.S.M.E., Purdue University, 1932*) product engineer, inventors in patents 2,942,055 and 2,942,059 for a storage battery and method for making storage batteries, respectively.

- **Harold V. Elliott,** (*General Motors Institute, 1938*) senior project engineer, and **Joe R. Canaday,** project engineer, inventors in patent 2,942,220 for a control device.

Detroit Diesel Engine Division
Detroit, Michigan

- **James O. McVicar,** foreman, Engineering Department, inventor in patent 2,939,548 for a blower housing and drive lubricating means.

Detroit Transmission Division
Ypsilanti, Michigan

- **Walter B. Herndon,** (*B.S.E., State College of Washington, 1928, and M.S.E., University of Michigan, 1930*) director of engineering and sales, inventor in patent 2,934,976 for an automatic plural step ratio transmission.

Diesel Equipment Division
Grand Rapids, Michigan

- **John Dornbos,** (*B.S.Chem., University of Grand Rapids, 1941*) experimental chemist; **Ellen L. Van Singel,** (*B.S. in chemistry, Mary Manse College, 1941*) experimental chemist; and **Charles H. Palmer,** (*B.S. Chem.E., Michigan State University, 1935*) chief metallurgist, inventors in patent 2,939,442 for a valve lifter.

Electro-Motive Division
La Grange, Illinois

- **Matt J. Weber, Jr.,** (*Illinois Institute of Technology*) senior project engineer, and John Markestein, deceased, inventors in patent 2,936,983 for a semi-trailer king pin locking and supporting means.

- **Robert H. Konsbruck,** (*International School of Correspondence*) senior project engineer, inventor in patent 2,939,063 for a wheel slip detection and control system.

- **Kenneth D. Swander, Jr.,** (*B.S.M.E., Purdue University, 1942*) assistant air brake engineer, inventor in patent 2,942,917 for a composite air brake and air suspension charging and signaling system.

- **Rudolph C. Weide,** (*M.E. degree, Berlin Technical Institute, Germany, 1923*) senior project engineer, inventor in patent 2,943,286 for a controller.

GM Engineering Staff
Warren, Michigan

- **Charles A. Chayne,** (*B.S.M.E., Massachusetts Institute of Technology, and Harvard University, 1919*) vice president in charge, GM Engineering Staff, inventor in patent 2,929,261 for a transmission selector control.

- **William J. Steinhagen,** (*B.S.E., 1947; M.S.E., 1948, University of Michigan*) assistant engineer in charge, Power Development Group; **Philip L. Francis,** project engineer; **Andries C. deWilde,** (*M.M.E., 1928 and M.E.E., 1931, Technical University of Delft, Holland*) senior project engineer; Zenon Popinski, not with GM; and **John G. Hart,** (*B.S.M.E., University of Rochester, 1950*) supervisor, wiper application, Delco Appliance Division, inventors in patent 2,932,286 for a windshield wiper actuating mechanism.

- **Gilbert K. Hause,** engineer in charge, Transmission Development Group, inventor in patent 2,932,939 for a hydraulic torque converter.

- **Carl A. Stickel,** (*B.M.E., The Ohio State University, 1927; LL.B., University of Dayton, 1932; and Master of Patent Law, University of Dayton, 1934*) patent attorney, Patent Section, Dayton office, inventor in patent 2,932,962 for a washing machine.

- **Gilbert K. Hause*; Burnette Heck,** (*Wayne State University, 1935*) senior project engineer, and **Oliver K. Kelley,** (*B.S., Chicago Technical College, 1925 and Massachusetts Institute of Technology*) now technical assistant to the general manager, Defense Systems Division, inventors in patent 2,934,177 for liquid cooled friction brakes.

- **Von D. Polhemus,** (*B.S.M.E., University of Cincinnati, 1933*) engineer in charge, Structure and Suspension Development

Group and **Max Ruegg,** (*M.E., Swiss Polytechnic, 1921*) assistant engineer in charge, Structure and Suspension Development Group, inventors in patent 2,934,352 for a vehicle fluid suspension.

- **Stanley H. Mick,** (*B.M.E., General Motors Institute, 1955*) project engineer, and **John Zimmerman,** (*Detroit City College*) senior design engineer, inventors in patent 2,938,545 for a fuel injection diaphragm mechanism.

- **Henry J. Leonard,** (*General Motors Institute, 1940*) section engineer, and **George J. Watt,** (*B.S.M.E., Lawrence Institute of Technology, 1949*) senior design engineer, inventors in patent 2,939,440 for an accessory drive engine.

- **Von D. Polhemus***, inventor in patent 2,939,698 for an air spring.

- **John S. Wroby,** (*B.M.E., University of Detroit, 1942*) design engineer, inventor in patent 2,939,720 for a road noise isolation means for a motor vehicle suspension support.

- **Gilbert K. Hause***, and **Burnette Heck***, inventors in patent 2,940,549 for a liquid cooled disc brake.

- **Lothrop M. Forbush,** (*B.S., Harvard University, 1939, and Massachusetts Institute of Technology*) engineer in charge, Vehicle Development Group; **James H. Stone,** (*B.S.M.E., Wayne State University, 1946*) section engineer; and **Walter H. Zimmerman,** (*B.S.M.E., University of Michigan, 1941*) design leader, inventors in patent 2,941,614 for a fluid pressure operated vehicle door lock.

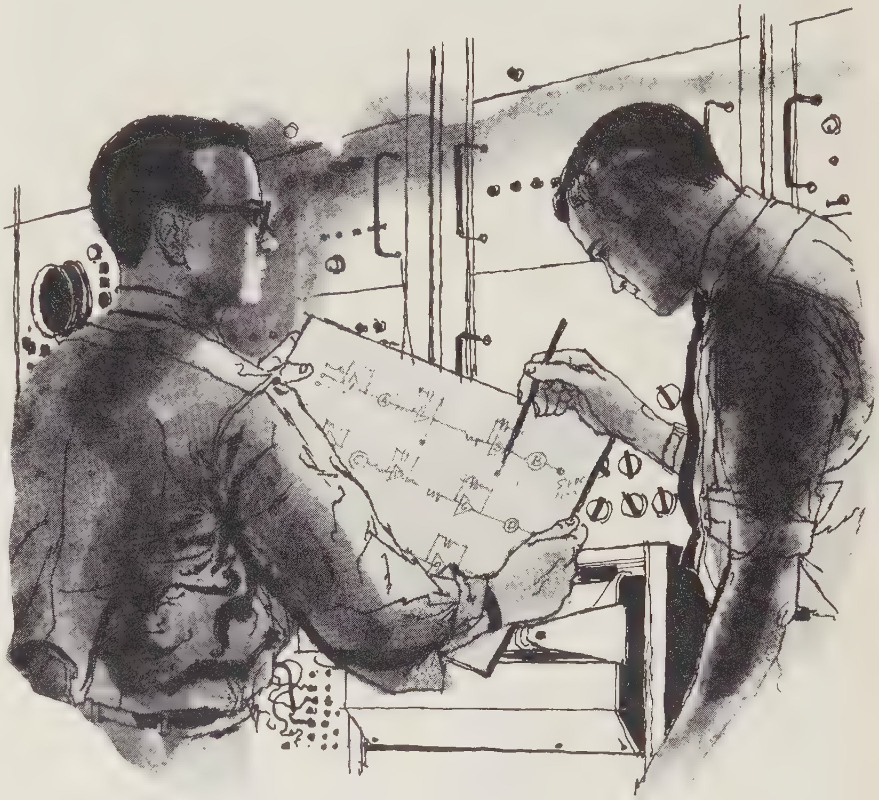
Euclid Division
Cleveland, Ohio

- **Janis Mazzarins,** (*Technical University, Aachen, Germany*) senior designer, inventor in patent 2,936,841 for a tractor suspension having resiliently mounted equalizer bar.

- **Louis F. Held,** (*B.S.M.E., University of Michigan, 1942*) chief design engineer, Product Engineering Department, and Stewart F. Armington, retired, inventors in patent 2,941,423 for a compound planetary gear drive.

- **Alvin A. Rood,** (*B.S. in Mathematics, University of Chicago, 1936*) senior designer, inventor in patent 2,941,547 for a valve assembly having infinitely variable load compensating flow control valve.

- **Ralph J. Bernotas,** (*B.S.M.E., and M.S.M.E., Case Institute of Technology*) senior product engineer, inventor in patent 2,941,612 for a vehicle having pivotally interconnected front and rear frame sections.



- **Anton Z. Panasewicz,** (*Fenn College, 1951*) layout man, inventor in patent 2,942,362 for a cross beam assembly.

Fisher Body Division
Warren, Michigan

- **Gerhard Rehkugler,** designer, and **James D. Leslie,** (*B.M.E., University of Detroit, 1939*) engineer in charge, Mechanical Department, inventors in patent 2,927,655 for a vacuum operated seat back lock.

- **Ernst R. Bidlingmaier,** (*Chrysler Institute of Engineering*) project engineer, and **Victor H. Dutchik,** (*Washington University*) assistant engineer in charge, body engineering, inventors in patent 2,930,652 for a roof rail molding and clip for a vehicle.

- **Charles P. Hooverson,** (*E. DeSmet Course in Automotive Body Design*) design leader, inventor in patent 2,933,784 for a weather seal structure.

- **Carl E. Hedeen,** (*Wayne State University*) senior engineer in charge of Body Engineering Activity—Design and Drafting; **James C. Louton, Jr.,** (*B.M.E., General Motors Institute, 1957*) layout draftsman; and **Henry J. Wubbe,** layout draftsman, inventors in patent 2,934,375 for a window clearance slot cover.

- **Louis P. Garvey,** (*B.M.E., University of Detroit, 1940*) assistant engineer in charge, Product Engineering Activity, Design and Drafting Department, inventor in patent 2,934,930 for a coincidental door locking system.

- **Edward A. Klimek,** (*B.I.E., General Motors Institute, 1946*) Baltimore plant superintendent, inventor in patent 2,935,080 for a conduit tender.

- **Louis P. Garvey***; **Charles J. Griswold, Jr.**, (*B.S. in engineering mechanics, Purdue University, 1953*) assistant engineer in charge, Body Engineering, Design and Drafting Department; and **James D. Leslie***, inventors in patent 2,935,351 for an automobile door latching means.

- **Engelbert A. Meyer**, senior project engineer, inventor in patent 2,936,668 for a stud retaining spring clip.

- **Ernest V. Harper**, (*B.S.E., Northwestern University, 1946 and University of Marquette*) production engineer, inventor in patent 2,936,806 for a weld nut.

- **Charles J. Griswold, Jr.***, and **James D. Leslie***, inventors in patent 2,937,043 for a mechanical door latch for a pillarless automobile.

- **James D. Leslie***, and **Henry J. Wubbe***, inventors in patent 2,937,045 for a door handle assembly.

- **William E. Sehn**, (*B.M.E., General Motors Institute, 1951*) engineer in charge, Product Evaluation Department, inventor in patent 2,938,245 for a weather sealing member structure.

- **Roy H. Milne**, senior layout draftsman, inventor in patent 2,938,249 for a weather strip assembly.

- **James D. Leslie***; **James C. Louton, Jr.***; and **Claud S. Semar**, (*Detroit City College, University of Michigan, and Wayne State University*) senior project engineer, inventors in patent 2,939,513 for a vehicle seat adjuster.

- **Bernard H. Keating**, body designer, and **Claude P. Sprunk**, (*General Motors Institute, 1941*) engineer in charge, Design and Drafting Department, inventors in patent 2,939,741 for a sunshade support assembly.

- **Robert M. Fox**, (*B.M.E., General Motors Institute, 1950*) senior project engineer, and Henry J. Faljole, Jr., no longer with GM, inventors in patent 2,941,826 for a windshield wiper clutch.

- **James H. Wernig**, (*Johnson School of Body Design and Engineering, and Alexander Hamilton Institute*) general director of engineering and related activities, inventor in patent 2,941,838 for a vehicle body.

Frigidaire Division
Dayton, Ohio

- **Thomas E. Davidson**, (*B.E.E., University of Dayton, 1951*) project engineer, and Edward J. Frey, not with GM, inventors in patent 2,928,267 for a laundry control system.

- **John H. Heidorn**, (*General Motors Institute, 1947*) project engineer, inventor in patent 2,929,551 for a refrigerating apparatus.

- **Verlos G. Sharpe**, (*B.S.M.E., Purdue University, 1948*) section engineer, inventor in patent 2,931,194 for an ice block harvesting device.

- **Laurence J. Mitter**, (*University of Cincinnati*) project engineer, inventor in patent 2,931,687 for a domestic appliance.

- **Lester M. Miller**, (*Dayton Art Institute, Art Academy of Cincinnati, and the Central Academy of Commercial Art*) junior engineer, inventor in patent 2,932,491 for a heat transfer unit.

- **Edward C. Simmons**, (*University of Dayton*) senior engineer, inventor in patent 2,933,905 for refrigerating apparatus.

- **Charles K. Billings**, (*B.S.M.E., University of Illinois, 1947*) supervisor, major product line, inventor in patent 2,933,912 for a dispensing device for a domestic appliance.

- **James W. Jacobs**, (*B.S.M.E., University of Dayton, 1954*) manager, research and future products engineering, inventor in patent 2,936,594 for a refrigerating apparatus with hot gas defrost.

- **Richard E. Gould**, (*B.S.M.E., 1923, and M.S.M.E., 1927, University of Illinois*) chief engineer, inventor in patent 2,936,598 for refrigerating apparatus.

- **Leonard J. Mann**, (*M.E., University of Cincinnati, 1940*) senior project engineer, inventor in patent 2,937,511 for multiple temperature refrigerating apparatus.

- **Robert F. Neidhart**, model maker, and **Harold M. Snyder**, layout draftsman, inventors in patent 2,939,305 for a lint filter for washing machine.

- **Keith K. Kesling**, (*University of Dayton and Dayton Art Institute*) project and design engineer, inventor in patent 2,939,465 for a domestic appliance.

- **Millard E. Fry**, (*B.S.M.E., University of Pittsburgh, 1931*) senior project engineer, inventor in patent 2,939,731 for a control shaft.

- **Edward C. Simmons***, and John Pas, not with GM, inventors in patent 2,940,277 for a defrosting system for a refrigerator.

- **Verlos G. Sharpe***, and **Everett C. Armentrout,** (*B.S. in physics, University of Dayton, 1957*) project engineer, inventors in patent 2,940,678 for an ice cracking device.

- **Lawrence L. Jaffe,** (*B.Chem.E., University of Cincinnati, 1931*) senior engineer, and **Wendell L. Harris,** (*B.S., Wooster College, 1929*) analytical chemist, inventors in patent 2,940,877 for paint stripping composition.

- **Robert Smith,** (*B.E.E., New York University, 1950*) senior project engineer, inventor in patent 2,942,894 for a conduit coupling having means for preventing damage to the coupling due to freezing water.

- **Harry F. Clark,** (*E.E., University of Cincinnati, 1921*) senior project engineer, inventor in patent 2,943,171 for electrical apparatus.

GMC Truck and Coach Division
Pontiac, Michigan

- **Loren T. Flynn,** (*B.S.E., Illinois Institute of Technology, 1926*) engineering consultant, fleet sales, and **Harold E. Fox,** (*Carnegie Institute of Technology*) development engineer, inventors in patent 2,932,988 for a transmission.

- **John J. Killinger,** (*M.E., University of Detroit, 1955*) project engineer, inventor in patent 2,934,356 for multiple control arrangement for air spring.

- **Theron E. Neir,** (*B.M.E., Lawrence Institute of Technology, 1942*) drafting supervisor, inventor in patent 2,935,055 for a concentric valve internal combustion engine.

- **Hans O. Schjolin,** (*B.S., Karlstad College, Sweden, 1920, and Polytechnical Institute, Mittweida, Germany, 1923*) staff engineer, and **Millis V. Parshall,** (*B.S.M.E., University of Michigan, 1918*) project engineer, inventors in patent 2,936,864 for a transmission drive mechanism for vehicles and the control system therefor.

- **Hans O. Schjolin***, inventor in patent 2,939,558 for a transmission.

Guide Lamp Division
Anderson, Indiana

- **Charles W. Miller,** (*Purdue University*) senior project engineer and **George W. Onksen,** (*B.I.E., General Motors Institute, 1956 and Purdue University*) staff engineer—reliability, inventors in patent 2,934,676 for a light responsive control system.

- **Eugene G. Matkins,** (*B.M.E., General Motors Institute, 1952*) senior project engineer—reliability, inventor in patents 2,935,646 and 2,939,052 for an automatic headlamp control circuit and an automatic headlight dimmer system, respectively.

- **George W. Onksen***; **Charles W. Miller***; **William E. Griner,** contact engineer; **Robert A. Martin,** (*Valparaiso Technical Institute*) detail project engineer; and **Kenneth R. Skinner,** (*B.S. in radio engineering, Tri-State College, 1955*) project engineer, inventors in patent 2,937,250 for a hermetically sealed relay.

- **Howard I. Slone,** (*B.S.E.E., Purdue University, 1938*) accessory engineer, and **Hugo H. Wendela,** Cadillac Motor Car Division, inventors in patent 2,938,697 for a control means for outside mirrors and the like.

Harrison Radiator Division
Lockport, New York

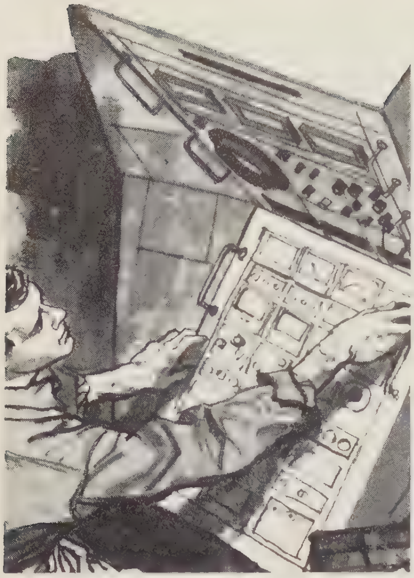
- **Fred D. Taylor,** senior project engineer; John R. Holmes, retired; and Robert R. Mandy, no longer with GM, inventors in patent 2,942,433 for a by-pass control in air conditioning systems.

Inland Manufacturing Division
Dayton, Ohio

- **Arthur J. Frei,** section engineer, inventor in patent 2,928,280 for a freezing device power unit.

- **Allen L. Everitt,** (*M.S.M.E., Purdue University, 1931*) section engineer; **James E. Frederick,** (*Sinclair College*) project engineer; and **Raymond C. Davis,** (*M.E., Dayton Night College, 1920*) administrative engineer, inventors in patent 2,930,640 for a flexible joint.

- **Julius J. Sabo,** tool engineer, and **Howard E. Butler,** (*B.I.E., General Motors Institute, 1947*) plastics engineer, inventors in patent 2,908,941 for a method for molding a ball-like article.



- **Edward P. Harris,** (*M.E., Cornell University, 1931*) section engineer, inventor in patents 2,931,063 and 2,935,003 for an apparatus and method for molding foam latex strips and the like and apparatus for making tubing, respectively.

- **Walter G. Kniffin,** (*B.M.E., Youngstown University, 1953*) project engineer, inventor in patent 2,943,164 for a wheel and horn switch assembly.

GM Manufacturing Development Staff
Warren, Michigan

- **Leonard Bolston,** (*B.S.E.E., Georgia Institute of Technology, 1951*) project engineer, and **John A. Bozymowski,** (*B.A., Michigan State Normal, 1956*) project engineer, inventors in patent 2,937,334 for heat transfer testing apparatus.

- **Edward J. Toton,** (*B.S.E.E., University of Michigan, 1953*) project engineer, and **Anthony S. Strzelewicz,** (*University of Detroit*) senior laboratory technician, inventors in patent 2,937,335 for an apparatus for evaluating quenching media.

- **Charles A. Nichols,** (*B.S.M.E., Carnegie Institute of Technology, 1923*) technical assistant to the vice president and **George L. Weiser,** chief process engineer, Process Department, Delco-Remy Division, inventors in patent 2,939,350 for metal working.

GM Overseas Operations Division
New York, New York

- **Eric J. Turney,** (*Luton College of Technology*) product engineer, General Motors Limited, Dunstable, England, inventor in patent 2,941,198 for electric horns.

- **Robert Schilling,** (*M.E. degree, Technical University, Munich, Germany, 1922*) special assistant to the chief engineer, Adam Opel A.G. Russelsheim, Main, Germany, inventor in patent 2,942,459 for torsion testing apparatus.

Packard Electric Division
Warren, Ohio

- **Robert H. Sims,** (*B.S.I.E., Illinois Institute of Technology, 1948*) Detroit district sales manager, inventor in patent 2,931,851 for a snap-in retainer for wiring harness.

- **Robert O. Schofield,** (*International School of Correspondence*) appliance assemblies co-ordinator, inventor in patent 2,935,156 for a combined air filtering and air disinfecting unit mounting.

- **Robert H. Sims*,** and **Herbert R. Lilley,** (*General Motors Institute, 1941*) sales manager, cable products, inventors in patent 2,941,059 for a printed circuit type fuse.

Pontiac Motor Division
Pontiac, Michigan

- **William K. Jensen,** (*Wayne State University and Lawrence Institute of Technology*) electrical development engineer, inventor in patent 2,933,597 for an electrical antenna control.

- **Christopher M. Drew,** (*B.A., Clare College, Cambridge, England*) design layout engineer, inventor in patent 2,934,051 for a rocker adjusting mechanism.

- **Mark H. Frank,** (*B.S.M.E., Michigan State University, 1927*) motor engineer, inventor in patent 2,936,745 for an engine cooling system.

- **Robert G. Campbell, Sr.,** senior designer, inventor in patent 2,936,990 for a hood mount.

- **Clayton B. Leach,** (*A.B. in mathematics and chemistry, Park College, 1934, and General Motors Institute*) chassis engineer, inventor in patent 2,939,748 for a drive shaft center bearing support.

GM Research Laboratories
Warren, Michigan

- **Robert F. Falberg,** (*B.S.M.E., Michigan College of Mining and Technology, 1948*) senior research engineer, inventor in patent 2,933,282 for a valve.

- **Robert L. Dega,** (*B.M.E., General Motors Institute, 1948*) supervisor, Mechanical Development Department, inventor in patent 2,935,365 for a seal.

- **John S. Collman,** (*B.S., Naval Architecture and Marine Engineering, University of Michigan, 1940*) assistant head, Engineering Development Department; **William A. Turunen,** (*B.S.M.E., Michigan College of Mining and Technology, 1939, and M.S., Columbia University, 1946*) head, Engineering Development Department; and **Paul T. Vickers,** (*B.M.E., General Motors Institute, 1948*) supervisor, Heat Transfer Section, Engineering Development Department, inventors in patent 2,937,010 for a regenerative heat exchanger.

- **Gene L. Leithauser,** (*B.S., Wayne State University, 1950*) assistant head, Polymers Department, inventor in patent 2,937,111 for a method of removing organic surface coating.

- **Eugene E. Flanigan,** (*B.S.M.E., Purdue University, 1950*) supervisor, Vehicle Applications Group; **Clark E. Quinn,** senior research engineer, and Frederick A. Creswick, no longer with GM, inventors in patent 2,938,338 for a gas turbine starting system.

- **James M. Ricketts,** (*General Motors Institute, 1944*) supervisor, engineering design, inventor in patent 2,938,661 for compressor seals.

- **John S. Collman*,** inventor in patent 2,938,713 for a regenerative heat exchanger.

- **Alexander Somerville,** (*B.S.E.E., 1943; M.S.E.E., 1947; and Ph.D., 1950, Northwestern University*) supervisor, Isotope

Laboratory, inventor in patent 2,939,013 for a measuring system.

- **Carl E. Bleil,** (*Ph.D., University of Oklahoma, 1953*) senior research physicist, inventor in patent 2,939,026 for a color television pickup tube.

- **Robert H. Kohr,** (*B.S.E., physics, 1950 and M.S.E., 1951, University of Michigan*) supervisor, Vehicle Dynamics Section, Engineering Mechanics Department, inventor in patent 2,939,470 for an automotive vehicle having free control and stability features.

- **Lubomyr O. Hewko,** (*B.S.M.E., Wayne State University, 1955*) design engineer, inventor in patent 2,941,539 for a governor.

- **Yro T. Sihvonen,** (*B.S., Antioch College, 1950; M.S., University of Michigan, 1954*) senior research physicist and **James E. Wilson,** (*General Motors Institute, 1933*) assistant head, Physics Department, inventors in patent 2,942,184 for a vehicle accelerometer.

Rochester Products Division
Rochester, New York

- **John B. Burnell,** (*Massachusetts Institute of Technology, and General Motors Institute, 1941*) assistant chief engineer, Research and Development Department, inventor in patent 2,938,507 for a single plane manifold.

- **Donald G. Dening,** (*A.A.S. in M.E., Rochester Institute of Technology, 1948*) project engineer and **Homer V. Krautwurst,** (*B.S.M.E., University of Rochester, 1941*) senior project engineer, inventors in patent 2,939,940 for a cigarette lighter and mounting therefor.

- **Adolph F. Braun,** (*B.S.M.E., University of South Dakota, 1928*) chief engineer, inventor in patent 2,941,778 for a four barrel carburetor.

- **Howard H. Dietrich,** (*B.S.E.E., Purdue University, 1926, and Yale University*) patents, new devices, and project analysis engineer, and Clarence H. Jorgensen, retired, inventors in patent 2,942,496 for a summing mechanism.

- **Lawrence C. Dermond,** (*Purdue University and Tri-State College*) staff engineer, inventor in patent 2,942,862 for a fuel injection metering control mechanism.

Saginaw Steering Gear Division
Saginaw, Michigan

- **Howard C. Brandt,** (*B.A., Michigan State University, 1949*) senior project engineer, inventor in patent 2,933,939 for a free-wheel ball nut and screw assembly.

- **Henry S. Smith,** (*B.S., Central Michigan University, 1938, and M.A., University of Michigan, 1940*) staff engineer—administration, and **Guy W. Wesson,** (*B.S.M.E., Michigan College of Mining and Technology, 1951*) project engineer, inventors in patent 2,936,643 for means for automatically maintaining steering gear over-center adjustment.

- **William B. Thompson,** (*B.M.E., General Motors Institute, 1950, M.S., Massachusetts Institute of Technology, 1960*) assistant chief engineer, and Aleksandrs V. Levensteins, deceased, inventors in patent 2,936,739 for fluid power steering.

- **Paul V. Wysong, Jr.,** (*University of Kansas*) sales supervisor, actuators, inventor in patent 2,942,775 for an air compressor with high turbulence head.

- **Dan R. Rowland,** (*B.S.M.E., Michigan State University, 1948*) project engineer, inventor in patent 2,942,902 for a joint closure.

GM Styling Staff
Warren, Michigan

- **Charles S. Lautenbach,** (*Chicago Technical College*) senior design engineer, and **Samuel C. Pollock,** (*University of Detroit*) senior design engineer, inventors in patent 2,930,651 for a convertible top linkage and actuating means.

- **Julius Hezler, Jr.,** senior design engineer, and **Joseph R. Schemansky,** chief designer, Preliminary Design Studio, inventors in patent 2,937,047 for a concealed drip gutter and passenger compartment ventilation means for an automobile vehicle.

- **Edward G. Podolan,** (*Lawrence Institute of Technology*) senior project engineer, Exterior Engineering and **Clark E. Quinn,** senior research engineer, Physics and Instrumentation Department, GM Research Laboratories, inventors in patent 2,938,749 for a vehicle closure and operating mechanism therefor.

- **Joseph H. Gilson,** general supervisor, Advanced Engineering Department, and **Victor M. Teerlinck,** senior design engineer, inventors in patent 2,939,511 for a pivoting seat.

- **Harry B. Dardarian,** group leader, Exterior Engineering and Drafting Department; **Joseph H. Gilson*,** and Gordon B. Swanson, no longer with GM, inventors in patent 2,939,742 for a foldable vehicle top.

- **Clarence I. Vellner,** senior design engineer, and James L. Schucker, no longer with GM, inventors in patent 2,940,375 for an air flow deflector device.

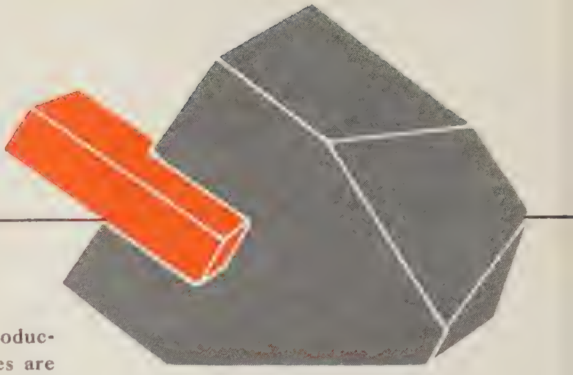
Ternstedt Division
Detroit, Michigan

- **Theodore F. Kramer,** (*University of Pennsylvania and Ryder College*) analyst—engineering data, inventor in patent 2,934,251 for a packaging device.

- **Paul L. Jones,** resident manager, Columbus, Ohio, plant, inventor in patent 2,936,553 for polishing discs.

A Typical Problem in Tooling Adaptable for Classroom Use:

Design a Fixture to Grind Identical Replacement Tool Bits



The working surfaces of a replacement tool bit may be ground to be identical reproductions of the original tool bit with the aid of a fixture designed so that its surfaces are parallel to the working surfaces of the tool bit. The design of the fixture involves working with compound angles and, in turn, the application of descriptive geometry fundamentals. The problem presented here is to design a fixture which will allow a one-point replacement tool bit to be ground so that its working surfaces are identical to those of the original cutting tool.

It often is necessary in machining operations that the working surfaces of replacement cutting tools be ground identical to those of the original cutting

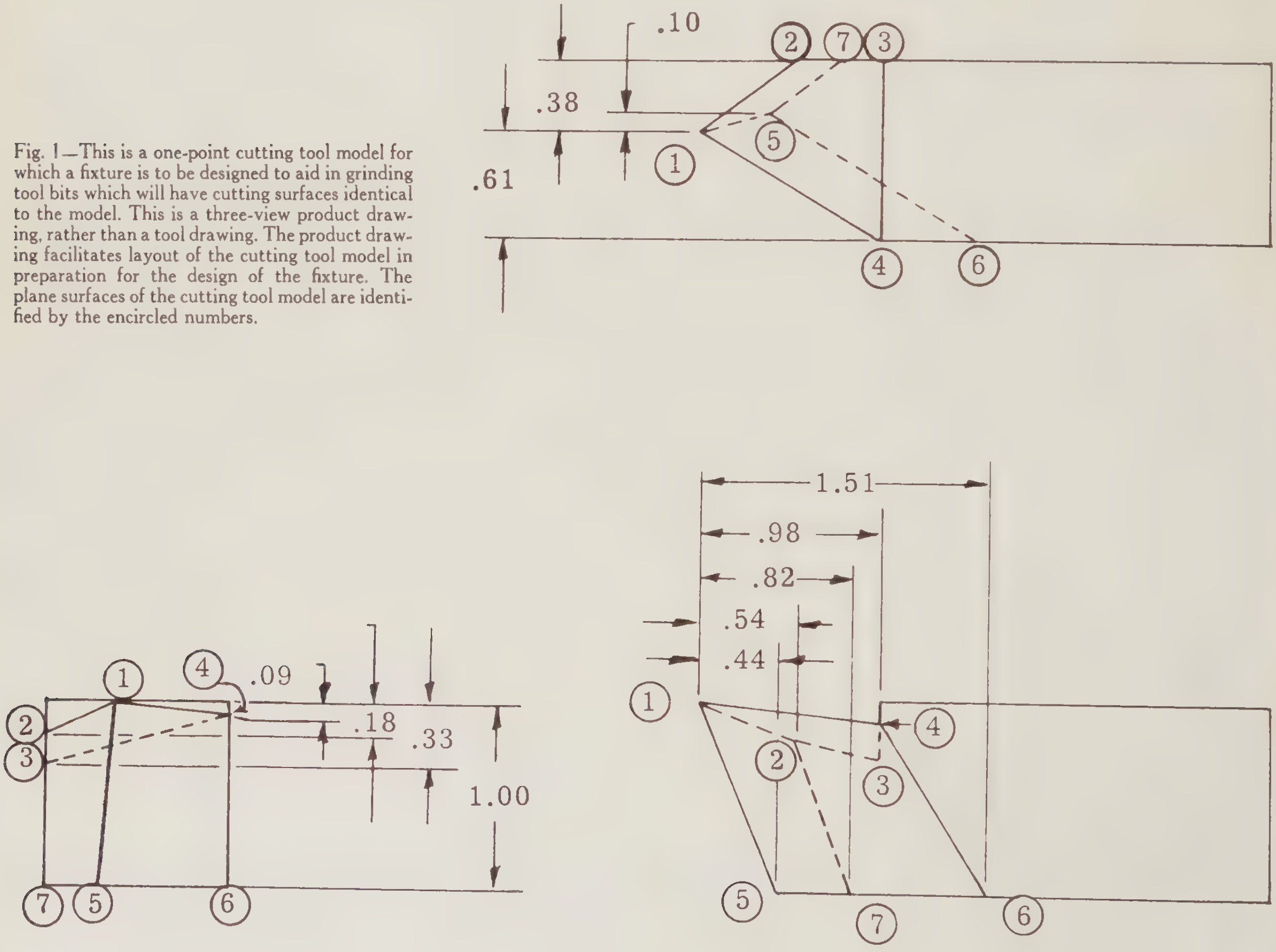


Fig. 1—This is a one-point cutting tool model for which a fixture is to be designed to aid in grinding tool bits which will have cutting surfaces identical to the model. This is a three-view product drawing, rather than a tool drawing. The product drawing facilitates layout of the cutting tool model in preparation for the design of the fixture. The plane surfaces of the cutting tool model are identified by the encircled numbers.

By THEODORE W. JUDSON
General Motors Institute

Apply descriptive geometry to analyze and design a cutting tool fixture

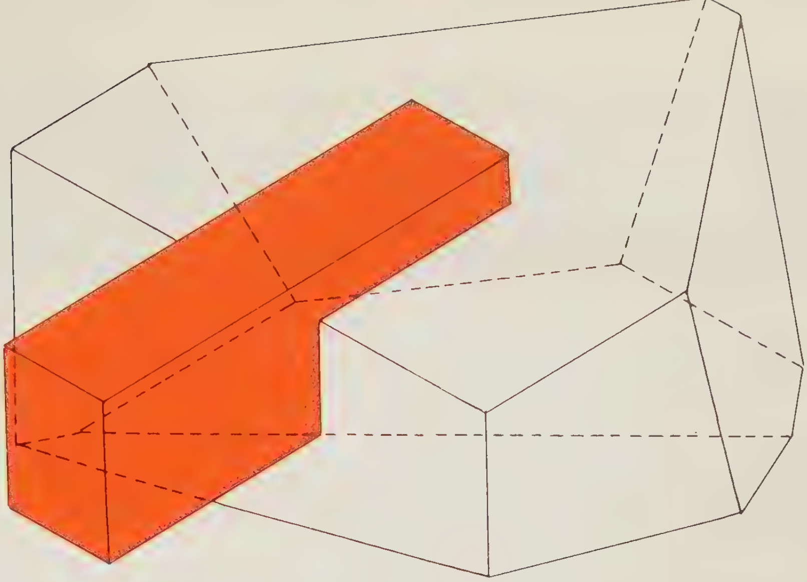


Fig. 2—The cutting edges of a tool bit may be ground to be identical to those of an original model with the aid of a fixture, such as illustrated here. The surfaces of this fixture, which does not necessarily represent a design used in industry, must be parallel to the surfaces which are to be ground on the tool bit blank (shown in color) mounted in the fixture.

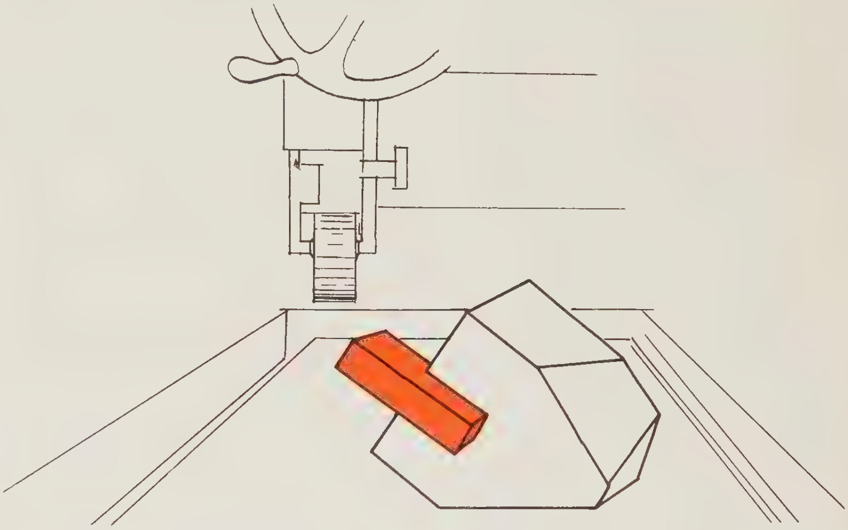


Fig. 3—When grinding the cutting surfaces of a tool bit with the aid of a fixture, each plane surface of the fixture is positioned on the table of a surface grinder. The surface produced on the tool bit (shown in color) by the grinding wheel will parallel the surface of the fixture which rests on the table.

tool if accuracy and surface quality are to be maintained. This is especially true in automatically controlled machining operations where cutting tools are replaced at pre-set time intervals. In such tooling set ups, frequent use is made of "throw away" inserts, or tool bits. These inserts, mounted in tool holders, are ground to specific rake, clearance, and relief angle requirements. Failure to grind the insert with the proper angles can materially affect the quality of the work produced.

In multi-machine operations, the working surfaces of the inserts must be identical if the same part is to be produced from several machines. If one insert is not ground to design requirements, the surface produced by that insert may cause the work piece to be rejected or reworked.

Even in a simple threading operation it is important that the thread cutters, or chasers, of the die or tap be ground to identical lead and clearance angles. Any damage to one chaser means that a new chaser must be ground to match the others. Here, again, identical reproduction of the original cutting tool is important to the quality of the thread.

Grinding the working surfaces of either a tool bit or thread chaser to match those of the original design may be achieved with the aid of fixtures especially designed for this purpose. The design of such fixtures usually involves working with compound angles. A fixture designed for use in grinding tool bits, for example, must provide for compound rake and clearance angles. A fixture designed for grinding thread chasers must provide for compound lead or clearance angles.

The design of a fixture used for grinding tool bits lends itself quite readily to a classroom problem illustrating a typical application of descriptive geometry fundamentals.

Problem

Assume that the design of a simple one-point cutting tool (Fig. 1) has been tested and found satisfactory for a particular metal removing operation. It is now desired to make a small, inexpensive fixture to aid in producing identical reproductions of the original cutting tool. The problem is to design such a fixture (Fig. 2) by applying principles of descriptive geometry. (The fixture illustrated in Fig. 2 does not necessarily represent a particular design used in industry.)

The surfaces of the fixture should be parallel to those of the cutting tool model so that when a tool bit blank is mounted in the fixture, and a surface of the fixture is placed on a horizontal table of a surface grinder, the grinding wheel will produce the same surface on the bit as appeared on the cutting tool model (Fig. 3).

The solution to the problem will appear in the January-February-March 1961 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

Technical Presentations by GM Engineers and Scientists

The technical presentation is another way in which information about current engineering and scientific developments in General Motors can be made available to the public. A listing of speaking appearances by General Motors engineers and scientists, such as that given below, usually includes the presentation of papers before professional societies, lecturing to college engineering classes or student societies, and speaking to civic or governmental organizations. Educators who wish assistance in obtaining the services of GM engineers and scientists to speak to student groups may write to the Educational Relations Section, Public Relations Staff, General Motors Corporation, General Motors Technical Center, Warren, Michigan.

The following GM personnel made recent technical presentations.

Automotive Engineering

Bart Cotter, chief engineer, Fisher Body Division, before the Society of Automotive Engineers, Detroit section, title: The Corvair's Challenge to the Body Builder.

T. M. Fisher, administrative engineer, GM Proving Grounds, before the Jackson chapter, Michigan Society of Professional Engineers, title: Automobiles and Proving Grounds, and before the Huron Valley Lions Club, Saginaw, Michigan, title: Proving Ground Testing.

Clare D. Harrington, administrative engineer, Oldsmobile Division, before the Lansing, Michigan, Lions Club, title: Styling of a New Car.

Frank W. Sinks, senior project engineer, Detroit Diesel Engine Division, before the Canadian Transit Association, Toronto, title: Diesel Exhaust Odor Control Progress Report.

From GMC Truck and Coach Division: **C. V. Crockett**, chief engineer, before the Detroit section, S.A.E., title: GMC V-6 and Twin Six Engines; **William P. Strong**, staff engineer, before the National Highway Users Conference, Newark, New Jersey, title: Motor Bus Safety; **Richard C. Balmer**, design engineer, before the Los Angeles section, S.A.E., title: GMC V-6 and Twin Six Engines; **Donald J. LaBelle**, assistant chief engineer, before the New York City section, S.A.E., title: New Trends in Lightweight Truck Design; and **W. M. Kennedy**, engine engineer, before the Montreal, Canada, Fleet Superintendents monthly meeting, title: GMC V-6 and Twin Six Engines.

From AC Spark Plug Division: **Wesley W. McMullen**, staff engineer, before the Automotive Council of Los Angeles, title: Engineering Aspects of Positive Crankcase Ventilation; **James H. DeVoe**, senior project engineer, before the Fleet Maintenance Association of Philadelphia, title: Oil Filtration; and **Robert Lay**, section manager, automotive spark plugs, before the Automotive Transportation Supervisors Association, Chicago, title: Designing Spark Plugs for Fleets.

From Chevrolet Motor Division: **Max M. Roensch**, assistant chief engineer, experimental tests, before the Western Petroleum Refiners Association annual meeting, San Antonio, Texas, title: Compact Cars and Their Effect Upon Refinery Requirements; **R. H. Clift**, senior engine development engineer, Chevrolet Operations, GM Proving Grounds, before the Virginia Polytechnic Institute annual engineering conference, Blacksburg, title: The Corvair Engine; **Walter R. Mackenzie**, director, engineering product information, before the National Bituminous Convention, Detroit, title: Chevrolet Truck Design, Testing, and Service Problems; **Garth Sayers**, senior project engineer, before the Indianapolis, Indiana, section, S.A.E., title: The Design of a Truck for Better Ride and Handling; **N. E. Farley**, staff engineer and director, Chevrolet Operations, GM Proving Grounds, before southeastern Michigan section, S.A.E., Lansing, member of panel discussing small cars; and **H. O. Flynn**, assistant chief engineer, truck body and chassis, before the National Bituminous Convention, Detroit, title: The 1960 Chevrolet Truck.

Chevrolet Motor Division engineering personnel who made the presentation, The Chevrolet Corvair, included: **R. P. Benzinger**, design engineer, before the Milwaukee section, S.A.E; **J. F. Bertsch**, design engineer, before the Kokomo, Indiana, Engineering Society and the "A" Section Tech Club, Detroit; **R. E. Denzer**, research and development engineer, before the University of Illinois student section, S.A.E.; **K. H. Hansen**, staff engineer, before the Chicago section, S.A.E.; **J. L. Hickey**, resident engineer, Toledo Transmission Plant, before the Fort Wayne, Indiana, section, S.A.E.; **N. E. Koch**, plant manager, Oakland, California, assembly plant, before the northern California section, S.A.E.; **P. J. King**, supervisor, Chevrolet Passenger Car Development Group, GM Proving Grounds, before the Ontario, Canada, section, S.A.E.; **R. C. Mangold**, resident engineer, Buffalo Manufacturing Plant, before the Pennsylvania State University student section, S.A.E.; **Emmett Moynihan**, product engineer, before the University of Michigan Engineers Club; **H. V. Nowalis**, resident engineer, Tonawanda, New York, Engine Plant, before the Rochester, New York, section, S.A.E.; **P. J. Passon**, resident engineer, St. Louis Assembly Plant, before the University of Colorado student section, A.S.M.E.; **W. D. Route**, assistant staff engineer, before the University of Michigan student section, S.A.E.; **F. J. Winchell**, director, research and development, before the Indiana section, S.A.E.; and **R. L. Westervelt**, resident engineer, Atlanta, Georgia, assembly plant, before the Birmingham, Alabama, Engineers Club.

From the GM Research Laboratories: **F. W. Bowditch**, senior research engineer, before the FISITA 8th International Automobile Technical Congress, The Hague, The Netherlands, title: Combustion Problems in Gasoline Engines; **J. R. Mondt**, research engineer, before the University of Denver student section, A.S.M.E., title: GMR Vehicular Gas Turbines; **W. A. Turunen**, head, Engineering Development Department, before students of the U. S. Military Academy, West Point, title: Progress in Automotive Gas Turbines; and **R. A. Wachsler** and **D. B. Learner**, senior research psychologists, before the Midwestern Psychological Association, St. Louis, title: An Analysis of Some Factors Influencing Seat Comfort.

Before the S.A.E. national automobile week meeting, Detroit: **F. W. Bowditch**, senior research engineer, GM Research Laboratories, title: A New Tool for Combustion Research; **R. H. Kohr,** supervisor, Engineering Mechanics Department, GM Research Laboratories, title: Analysis and Simulation of Automobile Ride; **Peter Kyropoulos,** technical director, GM Styling Staff, title: Automobile Aerodynamics; and **C. M. Rubly,** assistant staff engineer, Chevrolet Motor Division, title: Suspensions From the Ground Up.

Before the American Society of Lubrication Engineers national meeting, Cincinnati, Ohio: **J. J. Rodgers,** senior research engineer, and **M. L. Haviland,** research engineer, GM Research Laboratories, title: Friction Characteristics of Automatic Transmission Fluids as Related to Transmission Operation, and **P. A. Bennett,** supervisor, Fuels and Lubricants Department, GM Research Laboratories, title: Engine Rusting and the General Motors MS Test.

Before the S.A.E. annual summer meeting, Chicago: **C. W. Jackman,** assistant staff engineer, Chevrolet Motor Division, title: The European Approach to Braking Standards; **R. H. Wachsler,** senior research psychologist, GM Research Laboratories, title: Human Factors in Seating; **J. L. Lelli,** engineer in charge, Experimental and Development Department, Fisher Body Division, title: Engineering Passenger Car Front Seats for Maximum Comfort; **M. L. Haviland,** research engineer, and **J. J. Rodgers,** senior research engineer, GM Research Laboratories, title: Friction of Transmission Clutch Materials as Affected by Fluids, Additives, and Oxidation; **Earl L. Lindberg,** senior research engineer, GM Research Laboratories, title: Roundness and its Ramifications; **Vaughn H. Hardy,** chief engineer, Delco Appliance Division, prepared discussion on Problems Associated With Windshield Wiping; **F. W. Bowditch,** senior research engineer, and **T. C. Yu,** research engineer, GM Research Laboratories, title: A Consideration of the Deposit Ignition Mechanism; **W. C. Agnew,** research associate, GM Research Laboratories, title: End-Gas Temperature Measurements by a Two-Wavelength Infrared Radiation Method; **R. E. Sauzedde,** manager, clutch products, New Departure Division, title: Roller Clutch Design; **William D. Route,** assistant staff engineer, Chevrolet Motor Division, title: Gear Design for Noise Reduction; **Alex Hardy,** senior designer, Detroit Transmission Division, title: Manufacturing Considerations Affecting Gear Design; **Jack R. Doidge,** chief engineer, Detroit Transmission Division, title: Spragg Clutches; **David C. Apps,** head, Noise and Vibration Laboratory, GM Proving Grounds, prepared discussion on S.A.E. papers 203A and 203B; and **L. G. Johnson,** senior research mathematician, GM Research Laboratories, title: Proper Statistical Methods—Key to Successful Testing Programs.

Charles E. Ervin, Jr., chief project engineer—basic design, Detroit Diesel Engine Division, before the Common Carriers Conference Committee, Chicago, title: Basic 71E Engine Design Features.

L. R. Winters, senior specialist, General Motors Institute, before the Flint, Michigan, Breakfast Optimist Club, title: History of the Automobile Industry.

Paul C. Skeels, head, Experimental Engineering Department, GM Proving Grounds, before the Wilmington, Delaware, chapter of the Instrument Society of America, title: Automotive Proving Ground Instrumentation.

Craig Marks, assistant engineer in charge, Power Development Group, GM Engineering Staff, before the American Petroleum Institute, semi-annual meeting, Detroit, title: Piston Engines in the Space Age?

Bearings

M. E. Otterbein, assistant chief engineer, Hyatt Bearings Division, before the A.S.M.E. Spring Symposium on Load-Carrying Capacity of Bearings, New York City, title: Increased Capacity for Roller Bearings.

From New Departure Division: **T. W. Bakewell,** supervisor, general applications, and **Mark Goedecke,** eastern area engineering supervisor, before engineers of the Philadelphia Gear Works, King of Prussia, Pennsylvania, title: Ball Bearing Design and Selection; **C. T. Bragdon,** agricultural-textile engineer, before engineers of the International Harvester Company, Memphis, Tennessee, title: Progress in Seals for Implement Bearings; **Charles N. Hay,** supervisor, contracts, before the Lakeside, Ohio, Methodist Men's Club and the Greenwich, Ohio, Rotary Club, title: Bearings for Guidance Systems; **P. F. Reed,** supervisor, bearing service, before engineers of Thompson-Ramo-Wooldridge, Cleveland, title: Analysis Bearing Failures; and **Robert W. Walker,** project engineer, before engineers of Wagner Electric, St. Louis, and General Electric Company, Erie, title: Effect of Ball Bearings on Electric Motor Noise.

Ceramics

From AC Spark Plug Division: **Karl Schwartzwalder,** director of research and recipient of *Ceramic Age* magazine's Man of the Year award, before the Investment Casting Institute, State University of New York, Alfred, title: Injection Molding, and **Willard E. Hauth,** staff scientist, before the Northern California section, American Ceramic Society, title: Ceramics and the Ceramist at AC Spark Plug. Before the Materials and Equipment Division, A.C.S., Philadelphia: **A. A. Shukle,** research engineer, title: Casting Process for Forming Shapes Used in Firing Spark Plug Insulators, and **A. P. Watts,** experimental engineer, title: Tunnel Kiln Instrumentation and Control.

Computers and Data Processing

From Delco Radio Division: **R. B. Brown,** manager, military projects, and **H. W. McKenna,** senior engineer, before the Kokomo, Indiana, Junior Science Seminar, titles: Digital Computers and Analog Computers, respectively.

Charles M. Leech, manager, data processing, AC Spark Plug Division, Milwaukee plant, before the Marquette Management Club of Business Administration, title: Decision Making Through Data Processing.

T. A. Harris, project engineer, GM Engineering Staff, before the S.A.E., Detroit junior section, title: How the Engineer Can Use an Analog Computer.

From the General Motors Research Laboratories: **Barrett Hargraves,** research engineer, before the Industrial Mathematics Society, Detroit, title: GMR DYANA—A Breakthrough in Computer Programming; **Donald E. Hart,** assistant head, Special Problems Department, before Mackenzie Union's 13th Annual Career's Confab, Wayne State University, Detroit, title: Electronic Data Processing and before the Mechanical Engineering Seminar, Purdue University, title: Improving Communications Between Engineers and Computers; **D. B. Learner,** senior research psychologist, before the Institute of Radio Engineers, New York City, title: Development of the GMR Minimum Analog Driving Simulator; **J. T. Olsztyn**, senior mathematics programmer, before the IBM Programmer's Club, Yorktown Heights, New York, and before the 704 SHARE Users Organization, Los Angeles, title: The DYANA Programming System—Its Applications and Implications; **F. B. Quackenboss, Jr.**, research associate, before the American Society for Quality Control, greater Detroit section, Warren, Michigan, title: Statistical Decisions and Computers—Tools for Problem Solvers; and **T. J. Theodoroff**, research physicist, before the Association for Computing Machinery, Milwaukee chapter, title: The DYANA Programming System—Its Applications and Implications. Before the Western Joint Computer Conference, San Francisco: **Robert H. Kohr**, supervisor, Engineering Mechanics Department, title: Real-Time Automobile Ride Simulation, and **G. F. Ryckman**, supervisor, Special Problems Department, title: The Operator Oriented Language —A Computer Language.

Electrical Engineering

From Delco Products Division: **Henry K. Dexter**, supervisor, service publications, before the Refrigeration Service Engineering Society, Dayton, title: Basic Electricity, and **G. A. Neyhouse**, project engineer, before the National Service Engineers Society, Dayton, title: Electric Motor Control.

From Delco Radio Division: **E. R. Buehler**, technician, before the Kokomo, Indiana, Amateur Radio Club, title: Calculating and Using Pi Nets in Transmitters; **W. C. Caldwell**, field service engineer, before the electronics class, Port Arthur, Texas, College, title: Transistors—Fundamentals and Troubleshooting; **F. L. Hughes**, supervisor, field service, before armed forces personnel, Washington, D. C., title: Transistors—Fundamentals and Troubleshooting; **R. E. Lavengood**, regional manager, transistor sales office, Chicago, before engineers of McDonald Aircraft, St. Louis, title: Transistor Applications; **A. D. Rittmann**, manager, research and development—semiconductors, before members of the Five Talents Program, Flint, title: Semiconductor Devices; **W. C. Sahm**, field service engineer, before members of the graduate class in electronic instrumentation, Purdue University, title: Analyzing Transistor Circuits; and **J. S. Schaffner**, manager, evaluations and applications, before engineers of Chrysler Corporation, Detroit, title: Reliable Design with Power Transistors. Before the I.R.E. national meeting, New York City: **D. E. Brinkerhoff**, senior engineer, title: Calculation of the Gain-Frequency Characteristic Multi-Mesh Transistor Amplifier Stage Using a Programmed Computer, and **F. R. Kahn**, senior engineer, title: Environmental Tests for Automotive Electronic Components.

Thimios Jordanidis, special tester, Ternstedt Division, before the A.I.E.E. district conference of student members, Ann Arbor, Michigan, title: Electro-Mechanical Energy Conversion and the Generalized Machine.

Foundry

D. J. Henry, assistant head, Metallurgical Engineering Department, GM Research Laboratories, before the American Foundrymen's Society, Quad City chapter, Moline, Illinois, title: Planning for the 205th Century Foundry.

Edwin J. Pietrowicz, senior production engineer, Brown-Lipe-Chapin Division, before the Society of Die Casting Engineers, Anderson, Indiana, title: Analysis of Metal Flow Characteristics in Die Casting Dies.

Robert W. Metzger, faculty member, Production Engineering Department, General Motors Institute, before the Saginaw Valley chapter, American Institute of Industrial Engineers, Saginaw, Michigan, title: Least Cost Cupola Charging.

W. C. Walter, manager, Chevrolet Motor Division, Massena, New York, plant, before the S.A.E. national production meeting, Cleveland, title: The Chevrolet Aluminum Foundry Story.

From Central Foundry Division: **Elmer E. Braun**, works manager, before the Foundry Educational Foundation, Cleveland, title: A Full House; **Charles M. Eberhardt**, chief metallurgist, before the sand shop course and the malleable shop course of the A.F.S. Casting Conference, Philadelphia, titles: Have You Looked at Your Sand Lately and Malleable Pig Iron Versus Steel Scrap in the Malleable Cupola Charge; and **John L. Flitz**, product development engineer, before the A.F.S. training and research institute course on casting design and stress analysis, Chicago, title: Fundamentals of Good Casting Design and The Use of Stress Analysis.

Guided Missiles and Space Technology

R. E. Henderson, chief, applied physics, Allison Division, before the Institute of Environmental Sciences, Los Angeles, title: The Effect of Micrometeorites on Reflecting Surfaces.

J. P. Gillilan, assistant chief engineer, New Departure Division, before the Bristol, Connecticut, Kiwanis Club and Lions Club, title: Missiles and Their Guidance.

From AC Spark Plug Division's Milwaukee, Wisconsin, plant: **James H. Bell**, director, navigation and guidance, before the Saginaw chapter, Michigan Society of Professional Engineers, title: Missiles and the Space Age; **Robert G. Brown**, director, advanced concepts research and development, before professional people of the East District of Boy Scouts, Milwaukee, title: Missile Countdown; **Robert J. Budyak**, senior project engineer, before the Racine Astronomical Society, title: Astronomy and the Missile Program; **D. Dettmann**, engineer, before students and teachers, Audubon Junior High School science fair, Milwaukee, title: Science and Missiles; **Edward J. Eisele**, senior project engineer, before mechanical and electrical engineers, Milwaukee, title: Control Systems Involved in Guiding the THOR Missile; **Lewis A. Flaningam**, senior project engineer, before the 128th Aircraft Control and Warning Unit, Milwaukee, title: The Language of Missiles; **James D. Graham**, staff engineer, before teachers, graduates, and undergraduates of the National Physics Honorary Fraternity, Milwaukee, title: Inertial Navigation Principles, Systems, and Components—Present and Future; **Ralph E. Heilman**, senior project engineer, before a father and son group of Boy Scouts, Milwaukee, title: Missile Guidance Systems; **Michael J. Hadfield**, project engineer, before St. Agnes grade school students, Butler, Wisconsin, title: Astronomy and the Missile Program; **Edwin F. Katz**, director, technical education, before Explorer Scouts, Whitefish Bay, Wisconsin, title: Splitting Hairs; **Ted Koern**, project engineer, before the Whitefish Bay High School freshman science club, title: Guiding A Missile; **Floyd G. Mosier**, senior project engineer, before the S.A.E. student section, Marquette University, title: The Development of an Inertial Guidance System for a Ballistic Missile; **Paul Perry**, senior project engineer, before the American Rocket Society, Chicago section, title: Navigational Problems for Rocket Powered Vehicles; **Kenneth J. Schlager**, engineering project manager, before the Milwaukee, Wisconsin, Civitan Club, title: Inner Space—The Ocean; **Robert H. Wright**, head, engineering development laboratory, before students of the Campus Elementary School, Milwaukee, title: Missiles.

From AC Spark Plug Division, Flint: **W. J. McBride**, head, military and electrical engineering, before the Pontiac, Michigan, Exchange Club, title: Interesting Aspects of Missile Guidance.

Highway and Traffic Engineering

Kenneth A. Stonex, assistant director, GM Proving Grounds, before the 1960 Northwest Highway Engineering Conference, Corvallis, Oregon; the metropolitan section, Institute of Traffic Engineers, New York City; the 14th annual Ohio Highway Engineering Conference, Columbus; and the New Jersey Turnpike Authority, Newark; title: Roadside Design for Safety.

From the GM Research Laboratories: **J. W. Leggat, Jr.**, safety director, before the American Society of Safety Engineers, central Illinois chapter, Peoria, title: Inter-Relation of Vehicles and Roads; **Robert H. Kohr**, supervisor, Engineering Mechanics Department, before the A.I.E.E., Madison, Wisconsin, title: Automatic Guidance for Automobiles; **Robert Herman**, head, Theoretical Physics Department, before the Physics Colloquim, University of Chicago, title: Traffic Problems and before the Canadian Association of Physicists, London, Ontario, title: Remarks on Theory of Traffic Flow; **P. L. Olson** and **H. J. Bauer**, senior research psychologists, before the Midwestern Psychological Association, St. Louis, title: Judgment of Intervehicular Spacing; **H. M. Morrison**, research engineer, **E. A. Hanysz**, supervisor, Physics Department, and **A. F. Welch**, head, Electronics-Instrumentation Department, before the S.A.E. national automobile week meeting, Detroit, title: Automatic Highway and Driver Aid Developments; and **E. A. Hanysz**, before the I.R.E., New York City, title: Highway Alert Radio.

M. J. Garlick, executive engineer, Pontiac Motor Division, before the 2nd annual Oakland County, Michigan, Teen-Age Traffic Safety Conference, title: The Role of the Automobile Manufacturers in Traffic Safety.

Manufacturing

From the GM Manufacturing Development Staff: **Robert B. Colten**, staff engineer, before the Machinability Seminar, Pennsylvania State University, title: Numerical Control of Machine Tools; **Lynn T. Davies**, chemical engineer, before the 9th Southern and Municipal Industrial Waste Conference, North Carolina State College, Raleigh, title: Water—Conversation or Conservation; **Ward F. Diehl**, senior project engineer, before the 1960 Production Machine Tool Conference sponsored by Vickers, Incorporated, Detroit, title: Use of Fire Resistant Fluids; **George E. Groener**, senior engineer, before the S.A.E. national production meeting, Cleveland, title: Futures of Cold Extrusion; and **John Q. Holmes**, director, production engineering, before the Material Handling Institute, Pittsburgh, title: Material Handling in General Motors.

Gordon L. Isenhath, director, work standards, AC Spark Plug Division, before the Flint, Michigan, Shrine Club, title: Work Standards—What Is It.

From Fisher Body Division: **Jack Ogden**, senior engineer, before the Midwest Welding Conference, Illinois Institute of Technology, title: Resistance Welding in the Automobile Industry, and **Karl Sarafian**, senior production engineer, before the Detroit section, American Welding Society, title: Resistance Welding Controls Used by Fisher Body—Past and Present.

Before the 15th annual Purdue University Industrial Waste Conference: **A. Somerville**, supervisor, Physics Department, GM Research Laboratories, title: Waste Control at the GM Research Isotope Laboratory, and **Raymond A. Fisco**, junior process engineer, Brown-Lipe-Chapin Division, title: A Review of the Process of Hexavalent Chromium Reduction Utilizing Waste Flue Gas.

From Ternstedt Division: **Gerard J. O'Kane**, engineer in charge, Process Engineering and Laboratories, Columbus, Ohio, plant, before the 34th Ohio Sewage and Industrial Waste Treatment Conference, Columbus, title: Meeting the Varied Requirements of Industrial Waste Treatment, and **William E. Lovell**, engineer in charge, process engineering, before the 47th annual convention, American Electroplaters' Society, Los Angeles, title: Experience in the Operation and Performance of Dual Chromium Systems.

Metallurgy

Dean K. Hanink, chief metallurgist, Allison Division, before the Golden Gate Metals Conference, San Francisco, title: Metallurgical Tests as a Contribution to Pressure Vessel Reliability.

From Delco Radio Division: **Hans DeLaRoy**, metallurgist, before the Gem and Mineral Society of Indianapolis, title: Identification of Minerals by Their Structure and before the Kokomo, Indiana, High School Science Seminar, title: Spectroscopy in Industry.

Engineering personnel of Inland Manufacturing Division who made presentations before the American Society for Metals' Educational Course, Dayton, Ohio, chapter included: **Wendell W. Auwarter**, paint chemist, title: Organic Coatings; **Franklin E. Merica**, metallurgist; title: Metallic Coatings and Finishes; **Lloyd J. Reindl**, supervisor, paints and finishes, title: The Selection of Paints, Coatings, and Finishes; and **H. Otto Waag**, paint chemist, title: Application Techniques of Paints, Coatings, and Finishes.

From the GM Research Laboratories: **R. E. Marburger**, senior research physicist, before the American Society for Metals, New England regional meeting, Providence, Rhode Island, title: X-Ray Measurement of Residual Stresses in Hardened Steels; **D. E. Martin**, senior research engineer, before the A.S.M., Muncie, Indiana, title: Fatigue Testing; **C. F. Nixon**, head, Electrochemistry Department, before the S.A.E. national automobile week meeting, Detroit, title: Comments on Plating; **J. D. Thomas**, senior research engineer, before the American Electroplaters' Society, tri-state regional meeting, Cincinnati, title: Society Activities Pertaining to Durability of Decorative Electroplating; and **R. F. Thomson**, head, Metallurgical Engineering Department, before the A.S.M., Calumet, Illinois, chapter, title: Materials for the Automobile of the Future.

Miscellaneous

Harvey J. Meeusen, junior project engineer, Diesel Equipment Division, before the University of Wisconsin Engineering Institute on Engineering Nomography and the National Science Foundation's Summer Conference on Graphics in Scientific Engineering, Detroit, title: The Application of Nomograms to the Solution of an Engineering Problem.

F. R. Daley, staff engineer, Buick Motor Division, before the American Petroleum Institute, Detroit, title: An Equipment Designer's View of Progress.

Martin J. Caserio, general manager, Delco Radio Division, before graduating students of Western High School, Russiaville, Indiana, title: Milestones—Not Millstones.

Harry E. Welker, senior process engineer, Guide Lamp Division, before the American Electroplaters' Society, Rockford, Illinois, title: How to Train Foremen and Operators in the Most Efficient Application of Buffs and Compounds.

Worth M. Tyler, service engineer, Allison Division, before the A.T.A. maintenance facilities sub-committee meeting, San Francisco, title: Turbine Engine Cleaning—Processes and Equipment.

Bert T. Olson, plants manager, Delco Products Division, before the Ohio University chapter of Society for the Advancement of Management, 3rd annual regional conference, Athens, Ohio, title: Supervisors Work Too.

Raymond J. Schultz, senior project engineer, Saginaw Steering Gear Division, before the Industrial Management Conference, Saginaw, title: The Challenge of Change.

From the GM Research Laboratories: **W. D. Cheek**, senior research physicist, before the Society of Technical Writers and Editors, Warren, Michigan, title: Fission, Fusion, and Confusion, and **E. B. Jackson**, head, library, before the Milwaukee, Wisconsin, chapter of the Special Libraries Association, title: Information Service, European Style.

From the General Motors Institute: **Francis L. Mackin**, department chairman, engineering shops, before the American Society of Lubrication Engineers, Cincinnati, title: Training the User of Hydraulic Equipment and before the hydraulics class, Rockford, Illinois, Evening College, title: Fundamental Steps in the Design of Hydraulic Circuits; and **C. A. Brown**, administrative assistant in charge of faculty and instructional development, before the annual meeting of the A.S.E.E., Purdue University, title: The Role of English in the Proper High School Preparation for College.

From the GM Engineering Staff: **Roy P. Trowbridge**, director, Engineering Standards Section, before The Ohio State University's Annual Conference for Engineers and Architects, Columbus, title: Co-ordinating Industrial Standards With American Standard Practices; **Frank Graf**, GM Photographic Section, before the Standards Engineers Society sectional meeting, Detroit, title: Lensless Copying With Sensitized Paper; and **S. E. Kalmar**, assistant engineer in charge, Power Development Group, and **W. K. Steinhagen**, assistant engineer in charge, Power Development Group, before students of Michigan State University-Oakland, titles: Engineering Administration, and Technical Supervision—Project Co-ordination, respectively.

James W. Jacobs, manager, research and future products engineering, Frigidaire Division, before the Ohio Society of Professional Engineers, Cincinnati, title: Professional Development of Engineers.

From Fisher Body Division: **Arkady A. Lobanoff**, engineer in charge, front ends and instrument panels, before students of Southfield, Michigan, High, title: Capturing the Stylist's Dream, and **Harry A. Hunter**, supervisor of drafting, front ends and instrument panels, before students of Roseville, Michigan, High School, title: Capturing the Stylist's Dream.

Plastics

Robert C. Kennedy, staff engineer, GMC Truck and Coach Division, before the Society of Plastics Industries, Chicago, title: Plastics for Transportation.

Daniel Grzegorczyk, senior process development engineer, AC Spark Plug Division, before the Society of Plastics Engineers, Port Washington, Wisconsin, title: Epoxy Resins and Their Applications in Potting and Impregnating Electrical Components.

M. J. Somers, materials engineer, Delco Products Division, before the S.P.E., Dayton, Ohio, title: Chemistry of Plastics.

Irvin E. Poston, senior project engineer, GM Manufacturing Development Staff, before the Plastics Tooling Seminar, Purdue University, title: Recent Development in Plastics Tooling.

Engineering personnel of Inland Manufacturing Division who made presentations before the American Society for Metals' Educational Course, Dayton, Ohio, chapter included: **Joseph H. Overwein**, director of laboratories, title: Fundamental Aspects of Rubbers and Plastics, and **Robert F. Thome**, supervisor, rubber section, title: Basic Compounding of Rubbery Elastomers.

Before the Society of Plastics Industries meeting, Detroit: **Rudolph A. Ferrara**, senior project engineer, GM Styling Staff, title: Styling Advantages with Cellular Plastics, and **J. R. Wall**, head, Advanced Development Laboratory, Inland Manufacturing Division, title: Adaptability of Properties of Urethane Foam to the Design of Seat Cushions.

Robert L. Dega, supervisor, Mechanical Development Department, GM Research Laboratories, before the Detroit Rubber and Plastics Group, title: Seal Material Variables—A Source of Application Failures.

Quality Control and Reliability

H. E. Van Scoyk, assistant chief engineer, Frigidaire Division, before the American Home Laundry Manufacturers' Association, Hollywood-By-The-Sea, Florida, title: Quality in the 60's—Controls From the Viewpoint of the Supplier and the Manufacturer.

Engineering personnel from Delco Products Division who made presentations on Quality Assurance before the educational seminar of the Dayton, Ohio, chapter of the American Society of Tool and Manufacturing Engineers included: **Leo J. Nartker**, superintendent, quality assurance; **M. E. Feldstein**, manager, inspection and standards; and **R. C. Stockert**, supervisor, quality control.

Wallace E. Wilson, general manager, Rochester Products Division, before the Rochester, New York, chapter of the American Society for Quality Control, title: How Rochester Products Looks at Reliability.

Alan R. Townsend, manager of reliability, Allison Division, before the United Kingdom Symposium on Reliability, London, England, title: Organizing for Reliability.

C. V. Crockett, chief engineer, GMC Truck and Coach Division, before the

Rochester, New York, section of the S.A.E. and the Warren, Ohio, chapter of the A.S.Q.C., title: Engineering for Reliability.

Research

Before the Electrochemical Society, Chicago; **H. K. Becherer**, group leader, device engineering, Delco Radio Division, title: Effects of High Aluminum Concentration in Emitters of Germanium Alloyed Power Transistors, and **L. E. Gerlack**, device engineer, Delco Radio Division, title: Experimental Evidence of Surface Damage and Precipitation in Diffused Silicon.

Before the S.A.E. national aeronautic meeting, New York City: **J. D. Meador**, project engineer, Allison Division, title: Dynamic Testing of Gas Sampling Thermocouples; **R. J. Moffat**, senior research engineer, GM Research Laboratories, title: A Stable High Temperature Thermometry Rig; and **L. B. Haig**, research engineer, GM Research Laboratories, title: A Design Procedure for Thermocouple Probes.

From the GM Research Laboratories: **S. E. Beacom** and **B. J. Riley**, senior research chemists, before a seminar at the University of Pennsylvania, title: Radiotracer Techniques in Electrodeposition Studies; **J. D. Caplan**, assistant head, Fuels and Lubricants Department, before the American Petroleum Institute's Committee on Analytical Research, Detroit, title: Analytical Problems Associated with Vehicle Emissions; **F. E. Jamerson**, senior nuclear physicist, before the I.R.E., New York City, title: The Noble Gas Plasma Diode Thermionic Converter; **D. H. Loughridge**, head, physical research, before a Mechanical Engineering Department seminar, Northwestern University, title: Direct Conversion—Its Physics and Applications; and **D. W. Hardesty**, senior research engineer, before the American Electroplaters' Society, Detroit branch, title: Application of the CASS Test. Before the American Physical Society, Detroit: **L. D. Dyer**, senior research physical chemist, title: Evidence of Dislocation Interactions in Rolling Friction; **G. G. Scott**, research associate, title: Magneto-mechanical Determination of g Factors; **D. R. Boyd**, research engineer, and **Y. T. Sihvonen**, senior research physicist, title: Bridge for Evaluating Contacts to Photoconductors; **R. C. Frank**, senior research physicist, and **D. E. Swets** and **R. W. Lee**, research physicists, title: The Diffusion Coefficients of Helium in Fused Quartz; and **J. V. Laukonis** and **R. V. Coleman**, senior research physicists, title: Oxidation and Reduction Products on Iron Whisker Surfaces. Before the Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy: **T. O. Morgan**, research chemist, title: Chromatographic Analysis of Combustion Gases—A Simple Accurate Sampling System That Permits Calibration, and **P. K. Winter**, research associate, title: A Polarographic Method for the Determination of Chromic Acid in Copper Cyanide Plating Baths. Before the American Physical Society, Washington, D. C.: **Robert Herman**, head, theoretical physics, title: Formation of D, Li, Be, and B in an Expanding Universe, and **W. D. Cheek** and **F. L. Green**, senior research physicists, title: Beta-Ray Produced Photon Yields From Cl-36 Distributed in a Multi-Element Matrix. Before the American Physical Society, Houston, Texas: **Y. T. Sihvonen**, senior research engineer, and **D. R. Boyd**, research engineer, title: Contact Geometry and Detector Orientation Considerations in the Maximizing Photocurrents.

Science and Education

From AC Spark Plug Division: **Robert W. Smith** and **Willard E. Hauth**, staff scientists, before the Genesee County, Michigan, science teachers, titles: Physics in Industry and Trends in Science in the 60's, respectively.

From Delco Radio Division: **F. E. Jaumot, Jr.**, director, research and engineering—semiconductors, before members of the Five Talents Program, Flint, Michigan, title: Thermoelectricity. Before the Kokomo, Indiana, High School Science Club: **C. L. Meyer**, supervisor, materials research and advanced development, title: Chemistry; **J. L. Gregg**, project engineer, title: Electromagnetic Spectrum; and **W. E. Thompson**, head, applied mathematics group—military projects, and **R. F. Miller**, group leader, advanced development section, title: Mathematics.

H. M. Bendler, research associate, GM Research Laboratories, before the American Physics Teachers Association, Flint, Michigan, title: Physics in Industry.

Technical Careers and Vocational Guidance

Harold M. Dent, administrative chairman, cooperative engineering program, General Motors Institute, before students of Mt. Morris, Michigan, High School, title: Careers in Engineering.

Joseph J. Rosalik, senior project engineer, Cadillac Motor Car Division, before students of St. Alphonsus High School, Detroit, title: Drafting as a Career.

G. E. Smutny, drafting supervisor, Electro-Motive Division, before students of Proviso East High School, Maywood, Illinois, title: Drafting—an Engineering Fundamental.

Erwin G. Vertigan, supervisor, methods and plant layout, Brown-Lipe-Chapin Division, before students of Solvay, New York, High School, title: Automotive Engineering.

Harry Hawkins, director, sales and engineering, and **P. B. Zeigler**, chief engineer, Saginaw Steering Gear Division, before engineering students of Kansas State University, Manhattan, title: Creative Engineering.

1960 General Motors Conference for Engineering and Science Educators

The Ninth General Motors Conference for Engineering and Science Educators was held in Detroit July 10 through July 22. Forty educators representing 33 universities and colleges throughout the United States and Canada attended the two week Conference.

Co-hosts for the Conference, designed to acquaint educators with GM product, production, and research activities, were **Charles A. Chayne**, vice president in charge of Engineering Staff; **Anthony G. De Lorenzo**, vice president in charge of Public Relations Staff; **Lawrence R. Hafstad**, vice president in charge of Research Laboratories; **William L. Mitchell**, vice president in charge of Styling Staff; and **Philip J. Monaghan**, vice president in charge of Manufacturing Staff. **Kenneth A. Meade**, manager, Educational Relations Section, Public Relations Staff, was co-ordinator of the Conference.

A "Get Acquainted" dinner on July 10 started the Conference. **Mr. Chayne** welcomed the educators on behalf of the hosts and **Victor P. Matthews**, director, Salaried Personnel Section, discussed the Organization of General Motors.

On July 11 the educators visited the Research Laboratories at the GM Technical Center. After opening remarks by **John M. Campbell**, scientific director, the educators toured the various departments. Presentations were given by various members of the Research Laboratories which described current Research activities. **Howard A. Wilcox**, director of research and engineering, Defense Systems Division, addressed the group after lunch. During the evening session, presentations were given by **Gregory Flynn**, head, Mechanical Development Department, and **Robert Herman**, head, Theoretical Physics Department.

Harry D. Hall, director, Manufacturing Development, welcomed the educators during their July 12 visit to the Manufacturing Development Staff. The day's program included a tour of the staff's facilities and visits to a project approval meeting and a project review meeting. The evening session was under the chairmanship of **Louis G. Seaton**, vice president in charge of Personnel Staff. Members of his Staff who made presentations were **Earl R. Bramblett**, director, Labor Relations Section, and **George A. Jacoby**, director, Personnel Relations.

During the morning of July 13, the educators were guests of Styling Staff with **Mr. Mitchell** as host. The educators were given presentations on industrial design activities by **Leroy E. Kiefer**, executive-in-charge, Industrial Design, and members of his group, and on automotive body development by **Vincent D. Kaptur, Jr.**, assistant chief engineer, Body Development Studio.

In the afternoon, the group toured the Cadillac Motor Car Division with **Harold G. Warner**, general manager, as host. **Anthony G. De Lorenzo**, vice president in charge of Public Relations Staff, discussed GM public relations activities with the educators at the evening session.

On July 14, **Mr. Chayne** was host to the group at the Engineering Staff. Members of his Staff who made presentations were **Lyle A. Walsh**, manager, Engineering Staff Activities; **Craig Marks**, assistant engineer in charge, Power Development Group; **Lothrop M. Forbush**, engineer in charge, Vehicle Development Group, **Thomas Scott**, assistant engineer in charge, Passenger Car Section, and **Francis M. Coffey**, assistant engineer in charge, Automotive Ordnance Section, Vehicle Development Group; **Von D. Polhemus**, engineer in charge, and **Lawrence J. Kehoe**, administrative engineer, Structure and Suspension Development Group; **James E. Boyce**, supervisor, education and training; **Roy P. Trowbridge**, director, Engineering Standards Section; and **Harry C. Dumville**, director, New Devices Section.

Louis C. Lundstrom, director, GM Proving Grounds, addressed the group at the evening session. He also was host the next morning as the educators visited the Proving Ground at Milford, Michigan, for a tour of the laboratories and road system.

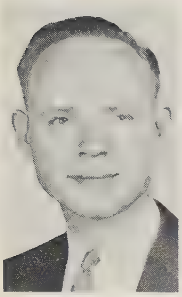
After the Proving Ground visit, the group traveled to General Motors Institute in Flint, Michigan. **Guy R. Cowing**, president, General Motors Institute, served as host and addressed the group. In the afternoon each educator visited the department of the Institute that interested him for consultation with faculty members and students.

From July 18 through July 20 each educator was on a field assignment to a GM division or Staff. On the evening of July 21 the group was addressed by **Cyrus R. Osborn**, executive vice president, General Motors.

A general session was held on the morning of July 22, at the GM Technical Center for comments and discussion led by the educators. In the afternoon, Dr. Clayton O. Dohrenwend, dean, Graduate School and School of Science, Rensselaer Polytechnic Institute, presented "Current Trends in Engineering Education." Following a discussion period, the Conference was adjourned.

Educators attending the Ninth GM Conference for Engineering and Science Educators were: FIRST ROW—*Charles L. McCabe*, Carnegie Institute of Technology; *Charles D. Cooper*, The Ohio State University; *Robert E. Redmann*, University of Bridgeport; Brother *Robert A. Thomson*, University of Dayton; *Gerald C. Zoerb*, University of Saskatchewan; *Donald T. Canfield*, Purdue University; *A. T. Olson*, University of Western Ontario; SECOND ROW—*Leon F. Osteyee*, California State Polytechnic College; *Melvin L. Manning*, South Dakota State College; *Ralph O. Gallington*, Southern Illinois University; *K. Ross Johnson*, Michigan College of Mining and Technology; *Douglas P. Adams*, Massachusetts Institute of Technology; *Neil MacCoull*, Columbia University; *Kenneth W. Woodfield*, General Motors Institute; *Floyd F. Rawlings*, Monmouth College; *Floyd L. James*, Miami University; *Robert N. Lehrer*, Northwestern University; THIRD ROW—*Joseph O. McGinnis, Jr.*, General Motors Institute; *Donald J. Renwick*, Michigan State University; *Wendell E. Miller*, University of Illinois; *Radnor J. Paquette*, Georgia Institute of Technology; *Clifton A. Anderson*, North Carolina State College; *Charles E. Taylor*, University of Illinois; *Dennis L. Moe*, South Dakota State College; *Robert H. Siegfried*, Cornell University; *Jervis M. Fulmer*, DePauw University; *George M. Kurajian*, University of Detroit; *Frank S. Roop, Jr.*, Michigan State University; *Donald L. Perkins*, Wayne State University; FOURTH ROW—*Clyde W. Johnson*, University of Michigan; *Robert S. Green*, The Ohio State University; *Robert A. Kolli*, Pratt Institute; *Lawrence A. Ware*, State University of Iowa; *Ernest L. Bickerdike*, University of California; *Jacob J. De Young*, Alma College; *Gordon J. Van Wylen*, University of Michigan; *James N. Siddall*, McMaster University; *Robert H. Gibbs*, Agricultural and Mechanical College of Texas; *Walter C. Hurty*, University of California at Los Angeles; and *Richard W. McDowell*, Purdue University. The Conference was held in Detroit July 10 through July 22.

Contributors to Oct.-Nov.-Dec. 1960 Issue of GENERAL MOTORS ENGINEERING JOURNAL



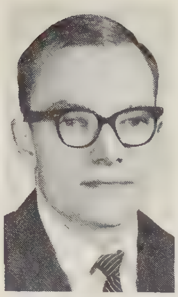
DONALD E. BRINKERHOFF,

contributor of "Applying a Digital Computer to Study the Frequency Response of a Transistor Audio Amplifier," is engineer-in-charge in the Acoustical Engineering Laboratory at Delco Radio Division. His present responsibilities include loudspeaker and associated audio-acoustical system design and development.

Mr. Brinkerhoff was granted a B.S. degree in electrical engineering from Purdue University in 1943 and has taken graduate work in mathematics and physics from the same school under the Purdue University Off-Campus Graduate Program at Delco Radio.

Mr. Brinkerhoff joined Delco Radio in 1946 as a specifications engineer and assumed his present position in 1952. During World War II he was an officer in the U. S. Army Signal Corps and served as an instructor in electrical communication engineering at the Massachusetts Institute of Technology Radar School. He also served as a member of the Army Ground Force Board II where he was responsible for new radar equipment evaluation.

His technical affiliations include membership in the Acoustical Society of America, the Professional Group on Audio in the Institute of Radio Engineers, the Audio Engineering Society, and the Kokomo, Indiana, Engineering Society. He is chairman of the subcommittee on Automotive Acoustics under the Committee on Electro Acoustics and Audio Devices in the Acoustical Society of America.



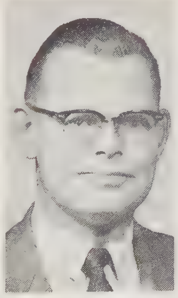
NORBERT J. DENIL,

contributor of "The Application of Nomography to the Design of a Two-Piece Propeller Shaft System" is a project engineer in the Engineering Test and Development Department at Cadillac Motor Car Division.

Mr. Denil joined Cadillac in 1952 as a General Motors Institute cooperative student. In 1957 he was granted a B.M.E. degree after completing the G.M.I. Fifth-Year Program. This Program included the writing of a project study report entitled "Analysis of Multi-Universal Joint Drive Lines." The nomograms presented in Mr. Denil's JOURNAL paper were developed as part of his Fifth-Year project study assignment.

Prior to assuming his present position in 1959, Mr. Denil gained experience at Cadillac as a senior detailer and layout man in design and drafting and as an experimental engineer. He is presently responsible for programming all computer work for Cadillac studies on vehicle performance and economy, drive line analysis, vibration, and car structure simulation.

Mr. Denil is a member of the Engineering Society of Detroit and the Vehicle Performance Subcommittee of the GM Committee on Engineering Computation. While at G.M.I. he was elected to Alpha Tau Iota. He is presently attending the Detroit Center of the University of Michigan where he is doing graduate study toward a master's degree in engineering mechanics.

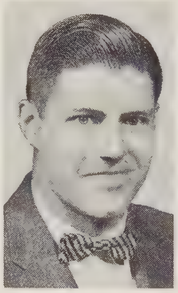


ROBERT B. GERHARDT,

contributor of "Court Made Law" and coordinator of this issue's "Notes About Inventions and Inventors," is a patent attorney in the General Motors Patent Section, Detroit Office.

Mr. Gerhardt's patent law work includes patent prosecution, infringement studies, and license negotiations primarily in the mechanical and electronic areas. Typical products involved are automatic transmissions, balancing machines, gas turbine engines, and electronic apparatus.

Mr. Gerhardt worked as an examiner in the United States Patent Office from 1948 to 1950. He then joined General Motors in the Washington Office of the Patent Section as a patent searcher. He was promoted to patent attorney in 1952 and a year later transferred to the Detroit Office. He received the B.S.M.E. degree in 1947 from Northwestern University and the LL.B. degree in 1952 from George Washington University. He is a registered patent attorney and a member of the District of Columbia and Michigan Bars. He is a member of the American Bar Association, Michigan Patent Law Association, Michigan Bar Association, and Phi Alpha Delta legal fraternity.



LESTER V. OSTRANDER, JR.,

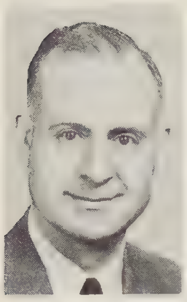
contributor of the problem, "Complete the Design of a Torque Measuring Instrumentation System," and the solution appearing in this issue, is a research engineer with the Electronics and Instrumentation Department of the GM Research Laboratories.

Mr. Ostrander joined the Research Laboratories in his present position after receiving the B.S.E.E. degree from Michigan State University in 1956.

Some of his previous major projects have been in the fields of instrumentation, dynamic measurements, and recording. He presently is concerned with micro-miniaturization, electronic driver aids, and transistor and semiconductor circuit design.

Mr. Ostrander authored the paper, "Desired Improvements in Instrumentation Used in the Automobile Industry," for the 1958 national convention of the Instrument Society of America.

His technical affiliations include membership in the Institute of Radio Engineers and the Instrument Society of America. He also is a member of Eta Kappa Nu, Pi Mu Epsilon, and Tau Beta Pi, honorary societies.



FRANKLIN L. RACINE, contributor of "A New Method for the Rapid Analysis of Metals in Industrial Waste Effluents," is chief chemist in the Metallurgical Department of GMC Truck and Coach Division. Included in his responsibilities is supervision of the Division's chemistry and spectrographic analysis work.

Mr. Racine joined GMC in 1929. Successive promotions led to his present position. He attended Wayne State University and also holds two certificates—one in chemical engineering and one in industrial metallurgy—from the International Correspondence Schools.

The technical affiliations of Mr. Racine include membership in the American Chemical Society and the American Society for Metals. He also is a member of several General Motors technical committees including the GM Analytical Chemistry Committee, the GM Spectrographic Committee, and the GM Hazardous Materials Committee.

DR. ROBERT W. SMITH, contributor of "An Evaluation of Thermistors: Thermally Sensitive Semiconductors," is a staff scientist and supervisor of the Physics and Chemistry Laboratory at AC Spark Plug Division. He currently is engaged in the development of new metallic, elastomeric, and paper materials for spark plugs and other automotive components such as fuel pumps, oil filters, and air cleaners.

Dr. Smith joined AC as a senior project engineer in April 1935, after two years with the University of Michigan Engineering Research Department. He assumed his present position in 1959.

The University of Chattanooga granted Dr. Smith the B.S. degree in physics in 1929. He received a Ph.D. degree, also in physics, from the University of Michigan in 1933. He was elected to Sigma Pi Sigma, Sigma Xi, and Blue Key honorary societies.

Dr. Smith's research in the field of spark plug and electrical instrument design has resulted in the granting of 21 patents. He has been co-author of four papers on spectrographic analysis topics. His technical affiliations include membership in the American Society for Metals, American Institute of Electrical Engineers, Optical Society of America, American Association for the Advancement of Science, American Physical Society, and the American Society for Testing Materials.

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ENGINEERING

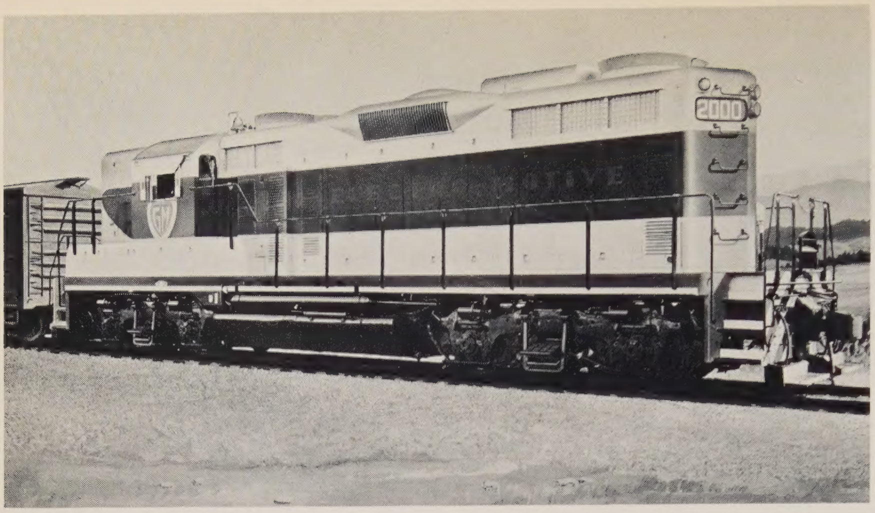
ASSIGNMENT IN GM

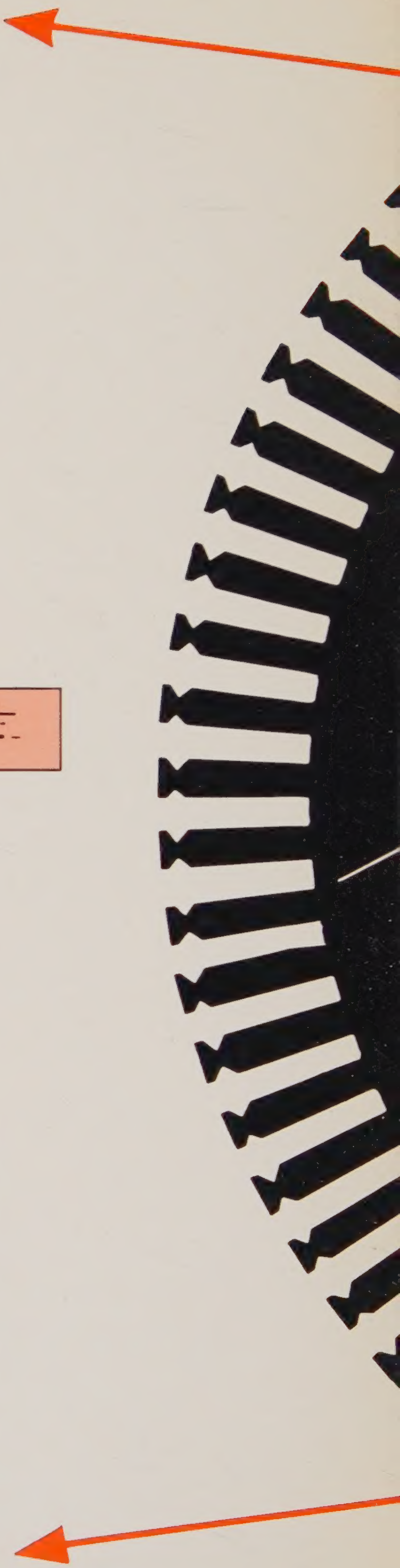
Engineers at the Milwaukee plants of AC Spark Plug Division have experimented for several years with applications of radiometry. Participants in one of these experiments were project engineer Dana K. Nance (left) and field service engineer Charles Stanford (right). They are shown in AC's Advanced Concepts Research and Development Laboratory with radiometric equipment used in a recent experiment in the North Atlantic Ocean around Newfoundland. Mr. Nance is holding a tape which provides information showing the effectiveness of radiometry as an all-weather detection device.

Last year the U. S. Navy awarded AC a contract to design and build a radiometric sextant. As a navigational aid, the radiometric sextant can determine the direction of true north with at least five times the accuracy of a conventional marine compass. Using highly sensitive amplifying devices, the radiometric sextant tracks radiation from the sun and moon and, thus, can operate in any weather.

Mr. Nance is a 1951 graduate of Vanderbilt University. Following graduation, he entered the U. S. Air Force where his interests led him to considerable training and experience in electronics work. After leaving the Air Force, he studied physics at Purdue University, and, in 1957, obtained a summer job working on radiometry at AC Spark Plug Division. He remained at AC, advancing to junior engineer and to his present position, project engineer.

Mr. Stanford joined AC as a junior engineer trainee after his graduation from the University of Wisconsin in 1952 with an electrical engineering degree. He became interested in field service and subsequently was assigned to engineering maintenance work on bombing navigational computers, bomb sights, and missile guidance systems at several U. S. locations as well as overseas. In this radiometry program, he participates in the early stages of product development to aid his field service work later on.





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